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TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

Volume 92, Numbers 1 and 2 1999

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907

Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 1-14

received 3/24/98
accepted 8/20/98

Shoot Production and Rooting Ability of Cuttings From Juvenile Greenhouse Loblolly Pine Hedges

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ABSTRACT

Rooted cutting technology to produce loblolly pine (*Pinus taeda* L.) planting stock for reforestation is currently being explored as a complement to seedling propagation from a seed orchard program. Since both genetic and non-genetic factors are likely to influence rooting efficiency, an understanding of these influences is important in order to develop a successful rooted cutting program. The objective of this study was to determine the genetic control of shoot production and rooting ability of greenhouse-grown loblolly pine hedges over several rooting cycles. Results of this investigation indicate that genetic control of rooting ability is strong. Selection for high rooting percentages should prove to be a useful strategy for advancing the vegetative propagation of loblolly pine.

INTRODUCTION

Rooted cutting technology to produce loblolly pine (*Pinus taeda* L.) planting stock for reforestation is currently being explored as a complement to seedling propagation from a seed orchard program (Frampton and Hodges, 1989; Foster and Shaw, 1987; Hughes, 1987). Many potential benefits of this technology have been recognized including increased genetic quality and uniformity of the planting stock deployed (Frampton and Hodges, 1989; Libby, 1985; Zobel and Talbert, 1984).

Since both genetic and non-genetic factors are likely to influence rooting efficiency, an understanding of these influences is important in order to develop a successful rooted cutting program. Thus, the objective of this study was to examine the genetic control of shoot production and rooting ability of greenhouse-grown loblolly pine hedges over several rooting cycles. The results of this study are compared to those from similar studies previously reported (Foster, 1978; Foster, 1990).

MATERIALS AND METHODS

Production and Rooting of Cuttings

During December 1988, ten seeds from each of nine full-sib families arranged in a 3 x 3 factorial mating design were germinated. Throughout the duration of the study, these seedlings were grown in 5.36 l pots in the greenhouse and maintained as hedges in order to increase the number of shoots usable as cuttings and to delay the maturation process. Each tree was hedged 6 times (6 cycles, Table 1) to a height of approximately 45 cm. Six to eight weeks after each hedging, the number of shoots greater than 7 cm in length was assessed.

At the same time shoot numbers were assessed, cuttings approximately 7 cm in length were collected from shoots 10 cm or greater in length. Cuttings were selected at random from all available shoots on a tree. These cuttings were set into 3.1 x 3.1 x 6.3 cm cells of Styrofoam flats® (Todd Planter Flats) filled with a 5:3:1 mixture by volume of perlite, sand, and peat. Cuttings were not treated with auxin. Flats of cuttings were placed in an air-conditioned, polyethylene-covered mist bench maintained at 28 ± 5°C. Cuttings were assessed for rooting at approximately two week intervals for 16 to 20 weeks starting with the first indications of rooting. Twelve to 16 weeks after setting, most rooting was completed and cuttings were transferred to an open mist bench.

Experimental Design and Data Analyses

In each of the rooting cycles, clonal plots were arranged in a completely randomized design within the rooting bench. Each plot consisted of 8 to 32 cuttings and each clone was represented by 2 to 4 plots per rooting cycle. Analyses of variance (Table 2) were performed on the number of shoots produced per hedge and on plot rooting percentages. Shoot production data were available for all 6 cycles. Rooting percentages were only available by family and clone for cycles 2 through 5. Cuttings produced after the first hedging were used in another study in which tree identification of cuttings was not maintained.

Prior to conducting the analysis of variance, data were checked to determine whether the assumptions for the analyses of variance were fulfilled. Untransformed data appeared to fulfill the assumptions as well as the transformed data. All further analyses were conducted using the untransformed data.

Variance components for all effects were estimated using the VARCOMP procedure of SAS (SAS Institute Inc., 1985). The percentage that each effect's variance component contributed to the sum of all the variance components was calculated. Total genetic variance (V_G), phenotypic variance (V_P), additive genetic variance (V_A), dominance genetic variance (V_D), and epistatic genetic variance (V_I) were calculated using methods described by Foster (1990):

$$V_G = \sigma^2_M + \sigma^2_F + \sigma^2_{MF} + \sigma^2_{C(MF)}$$

$$V_P = V_G + \sigma^2_{TF} + \sigma^2_{TM} + \sigma^2_{TFM} + \sigma^2_E$$

$$V_A = 2(\sigma^2_F + \sigma^2_M)$$
$$V_D = 4(\sigma^2_{FM})$$
$$V_I = \sigma^2_{C(MF)} - (\sigma^2_F + \sigma^2_M) - 3(\sigma^2_{MF})$$

Narrow-sense heritability (h^2), narrow-sensed heritability based on full-sib family means (h^2_F), broad-sense heritability (H^2), and broad-sensed heritability based on clone means (H^2_C) were estimated using the following formulae:

$$h^2 = \frac{2(\sigma^2_M + \sigma^2_F)}{V_P}$$

$$H^2 = \frac{V_G}{V_P}$$

$$h^2_F = \frac{\sigma^2_F + \sigma^2_M}{\sigma^2_M + \sigma^2_F + \sigma^2_{MF} + \frac{\sigma^2_{C(MF)}}{c} + \frac{\sigma^2_{TF}}{t} + \frac{\sigma^2_{TM}}{t} + \frac{\sigma^2_{TMF}}{t} + \frac{\sigma^2_E}{tc}}$$

$$H^2_C = \frac{V_G}{V_G + \frac{\sigma^2_{TF}}{t} + \frac{\sigma^2_{TM}}{t} + \frac{\sigma^2_{TMF}}{t} + \frac{\sigma^2_E}{tc}}$$

Table 2 provides definitions of formula components.

Total genetic correlation (r_G) and additive genetic correlation (r_A) between shoot production and rooting percentages of juvenile loblolly pine were calculated for Cycles 2 through 5 (Falconer; 1989).

RESULTS

Shoot Production

Shoot production of greenhouse hedges is illustrated in Figure 1. There was a large increase in the number of shoots produced after the first cycle with little change thereafter. Variance among hedging cycles accounted for 41.7% of the total variation in shoot production (Table 3).

Total shoot production over the first 6 cycles among half-sib and full-sib families ranged from 197 to 263 and 181 to 291, respectively (Table 4). Variation among female but not male parents was statistically significant. Male and female sources of variation accounted for 0.0% and 9.7% of the total variation, respectively. Male x female variation was not statistically significant and accounted for only 3.1% of the total variation. Figure 2 shows shoot production over time by family means.

Significant variation occurred among trees within families. Among-tree variation accounted for 11.9% of the total variation. Correlations between hedge cycles for shoot

production ranged from 0.36 to 0.61 and were statistically significant ($p<.05$) (Table 5). Family by hedging cycle variance (genotype by environment interaction) was significant, but only accounted for 2.1% of the total variation.

Heritability and variance estimates for shoot production of juvenile hedges are listed in Table 6. Additive genetic variance was 1.5 times as large as dominance genetic variance. Shoot production of loblolly pine was moderately controlled by additive genetic effects. Improved selection for shoot production is possible by selecting on family means or clone means.

Rooting Ability

Overall rooting percentages steadily decreased throughout the study from a high of 75% to 28% for cycles 1 through 5. Variance among rooting cycles accounted for 11.1% of the total variation in rooting (Table 3) for cycles 2 through 5.

Rooting percentages ranged from 19.4% to 40.8% among half-sib families and 11.5% to 55.3% among full sib-families (Table 4). Neither variation among female nor male parents was statistically significant. Male and female sources of variation accounted for 0.0% and 13.7% of the total variation, respectively. Male x female variation was statistically significant and accounted for 21.8% of the total variation. Figure 2 shows average percent rooting by family for rooting cycles 2 through 5.

Clonal rooting percentages ranged from 0% to 100%, 0% to 93%, 3.2% to 100%, and 0 to 75% within cycles 2 through 5, respectively. Significant variation occurred among clones within families. Among-clone variation accounted for 23.8% of the total variation. Correlations between rooting cycles for clonal rooting percentage ranged from 0.53 to 0.69 and were statistically significant ($p<.05$) (Table 5). Family by rooting cycle variance (genotype by environment interaction) was significant, but accounted for only 2.7% of the total variation. Variation in rooting among plots was the largest source of variation, accounting for 28.8% of the total variation. However, this proportion was considerably less than the 46% and 70% reported by Foster (1990) and Foster (1978).

Heritability and genetic effect estimates for rooting percentages are listed in Table 6. For purposes of comparison, results from Foster (1978) and Foster (1990) are also included in Table 6.

Additive genetic variation was only 1/3 of dominance genetic variation. This finding agrees with Foster's (1978) finding of nonadditive genetic variance 2.2 times as large as additive genetic variance for loblolly pine. However, Foster (1990) found additive genetic variance to account for almost all of the total genetic variance in loblolly pine.

Relationship between Rooting Ability and Shoot Production

Additive and total genetic correlation between shoot production and rooting of cuttings from juvenile hedges was -0.88 and -0.32 respectively. While the number of shoots produced and percent rooting of clones for the cycles 2 through 5 were negatively correlated, only the correlations in Cycles 2 and 3 cycles were significant. Based on the results of this study, selection for rooting may have an adverse impact on the shoot production of hedges.

DISCUSSION AND SUMMAY

Genetic control of rooting ability in loblolly pine appears to be strong. Selection for rooting ability both among and within families could provide substantial increases in rooting percentages. Screening and selection for rooting ability would be an obvious way to enhance the efficiency of a rooted cutting system. However, selection for rooting ability may constrain the improvement possible for growth and disease resistance.

Performance levels for productivity traits of the nine full-sib families used in this experiment are listed in table 7. Performance levels are used by the North Carolina State University Tree Improvement Cooperative to determine the relative worth of specific crosses in a tree improvement program (Hatcher et al, 1981). Family 27-5x27-6 is the best for growth, family 27-4x27-6 is the best for fusiform rust resistance, and family 27-4 x 27-2 is the best for both growth and rust resistance combined. However, none of these three families are among the best for rooting ability. Families 27-3x27-1 and 27-6x27-1 are the two best for rooting ability, but neither have exceptional performance levels for growth or rust resistance. With only six parents and nine full-sib families (3 x 3 factorial mating), it is not possible and was not the intent of this study to select full-sib families with outstanding performance levels for productivity traits (growth and disease resistance) that also have high rooting percentages. However, data from this study illustrates the potential reduction in selection intensity for growth traits associated with culling for rootability (Table 8).

Results of this investigation confirm that genetic control of rooting ability is strong. Selection for high rooting percentages should prove to be a useful strategy for advancing the vegetative propagation of loblolly pine.

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Table 1. Hedging and setting dates of loblolly pine hedges and cuttings.

Cycle	Hedging Date	Setting Date	Average Number Cuttings per Hedge
1	4/89	6/89	14.4
2	6/89	8/89	50.2
3	12/89	2/90	39.6
4	4/90	5/90	35.3
5	5/90	7/90	39.4
6	7/90	8/90	44.4

Table 2. Form of the analysis of variance for rooting percentages of loblolly pine cuttings. The clone(F*M) source becomes hedge(F*M) for the shoot production trait.

Source	Expected Mean Squares
Cycle (T)	$\sigma^2 + c\sigma^2_{TFM} + mc\sigma^2_{TF} + fc\sigma^2_{TM} + fmc\sigma^2_{T}$
Female (F)	$\sigma^2 + c\sigma^2_{TFM} + t\sigma^2_{C(FM)} + ct\sigma^2_{FM} + mc\sigma^2_{TF} + cmt\sigma^2_{F}$
Male (M)	$\sigma^2 + c\sigma^2_{TFM} + t\sigma^2_{C(FM)} + ct\sigma^2_{FM} + fc\sigma^2_{TM} + cft\sigma^2_{M}$
F*M	$\sigma^2 + c\sigma^2_{TFM} + t\sigma^2_{C(FM)} + ct\sigma^2_{FM}$
T*F	$\sigma^2 + c\sigma^2_{TFM} + cm\sigma^2_{TF}$
T*M	$\sigma^2 + c\sigma^2_{TFM} + cf\sigma^2_{TM}$
T*F*M	$\sigma^2 + c\sigma^2_{TFM}$
Clone(F*M)	$\sigma^2 + c\sigma^2_{C(FM)}$
Error	σ^2

where: c = # clonal plots per cycle, f = # females, m = # males, t = # cycles

σ^2_{T} = variance due to cycle effect

σ^2_{F} = variance due to female effect

σ^2_{M} = variance due to male effect

σ^2_{FM} = variance due to interaction of female and male effects

σ^2_{TF} = variance due to interaction of cycle and female effects

σ^2_{TM} = variance due to interaction of cycle and male effects

σ^2_{TFM} = variance due to interaction of cycle, female, and male effects

$\sigma^2_{C(FM)}$ = variance due to clone within female by male effect

σ^2 = error or plot to plot variance

Table 3. Degrees of freedom, mean squares, significance levels, variance components, and percent of total variation of shoot production and rooting percentages of loblolly pine cuttings.

Source	Degrees Freedom	Mean Squares	Variance Components	% of Total Variation
		Shoot Production		
Cycle (T)	5	13499.9*	142.4	41.7
Female (F)	2	7385.0*	33.1	9.7
Male (M)	2	1181.8	< 0.0	0.0
F*M	4	1033.4	10.7	3.1
T*F	10	621.9*	6.9	2.0
T*M	10	360.4	15.7	4.6
T*F*M	20	155.4*	7.1	2.1
Hedge(F*M)	80	329.7*	40.8	11.9
Error	400	85.2	85.2	24.9
Total	533			
		Rooting Percentage		
Cycle (T)	3	4541.0*	42.6	7.0
Female (F)	2	16529.2	834.0	13.7
Male (M)	2	5005.4	< 0.0	0.0
F*M	4	6205.4*	132.9	21.8
T*F	6	640.3	10.1	1.6
T*M	6	430.2	3.1	0.5
T*F*M	12	338.6*	16.3	2.7
Clone(F*M)	81	755.7*	145.8	23.8
Error	241	176.3	176.3	28.8
Total	356			

* = signficant at p<.05 level

Table 4. Average and clonal range (in parenthesis) of shoot production and rooting percentage of loblolly pine cuttings across rooting trials by family.

Female Parent	Male Parent 27-1	27-4	27-5	mean
	Shoot Production			
27-2	291[1] (210-400)[2]	217 (53-350)	281 (207-381)	263 (53-400)
27-3	207 (172-239)	186 (134-238)	198 (139-260)	197 (134-260)
27-6	181 (173-215)	207 (148-307)	244 (184-327)	211 (148-327)
mean	226 (172-400)	203 (53-350)	241 (139-381	224 (53-400)
	Rooting Percentage			
27-2	11.5[3] (2-22)[4]	25.0 (11-55)	21.6 (6-44)	19.4 (2-55)
27-3	55.3 (34-76)	24.8 (12-46)	35.1 (14-64)	38.4 (12-76)
27-6	54.0 (32-80)	37.9 (18-70)	30.4 (9-41)	40.8 (9-80)
mean	40.3 (2-80)	29.2 (11-70)	29.0 (6-64)	32.9 (2-80)

[1] Average of 10 clones summed over 6 hedging cycles.
[2] Range of 10 clones summed over 6 hedging cycles.
[3] Average of 10 clone means of 4 rooting cycles.
[4] Range of 10 clone means of 4 rooting cycles.

Table 5. Correlations between cycles for shoot production and rooting percentage. Correlations of family means are shown in the upper right corner of the table. Correlations of Clone means are shown in the lower left corner of the table. All correlations are significant at the <0.05 level.

	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Cycle 1		0.56[1]	0.67	0.67	0.81	0.73
		-	-	-	-	-
Cycle 2	0.59		0.66	0.80	0.77	0.92
	-		0.83[2]	0.95	0.84	-
Cycle 3	0.51	0.56		0.62	0.90	0.52
	-	0.65		0.87	0.74	-
Cycle 4	0.37	0.45	0.37		0.46	0.75
	-	0.69	0.65		0.81	-
Cycle 5	0.36	0.52	0.57	0.54		0.74
	-	0.57	0.53	0.58		-
Cycle 6	0.48	0.65	0.49	0.47	0.61	
	-	-	-	-	-	

[1] Shoot production.
[2] Rooting percentage.

Table 6. Estimates of genetic parameters for shoot production and rooting percentage of juvenile loblolly pine. Values from other published data are included for comparison.

Parameter	Shoot Prod.	Rooting Percent			
	Anderson et al[1]	Anderson et al	Foster 1990[2]	Foster 1978[3]	McKeand Frampton 1982[4]
Narrow-sense heritability (h^2)	0.33	0.26	0.15	0.07	0.26
Narrow-sense heritability based on family means (h^2_F)	0.60	0.31	0.46	0.06	0.45
Broad-sense heritability (H^2)	0.42	0.63	0.13	0.23	0.42
Broad-sense heritability based on hedge (shoot) and clone (rooting) means (H^2_C)	0.82	0.87	0.40	0.38	0.54
Total genetic variance (V_G)	84.5	351.8	103.7		
Additive variance (V_A)	66.1	146.3	116.2		
Dominance variance (V_D)	42.7	531.7	18.8		
Epistatic variance (V_I)	-24.4	-375.1	-31.3		

[1] Data from this publication.

[2] Foster, G.S. 1990. Genetic control of rooting ability of stem cuttings from loblolly pine. Can. J. For. Res. 20:1361-1368.

[3] Foster, G.S. 1989. Genetic variation in rooting stem cuttings from four year old loblolly pine. Weyerhauser Co., Hot Springs, AR. Tech. Rep. No. 042-3204/78/97.

[4] Annual Progress Report, 1982. Special Project on Tree Tissue Culture, Southern Forest Research Center, School of Forest Resources, N.C. State Univ.

Table 7. Rooting percent, performance level values for height growth, and fusiform rust resistance for each of the nine full-sib families.

Trait	Male Parent	Female Parent		
		27-2	27-3	27-6
Rooting[1]	27-1	11.5	55.3	54.0
	27-4	25.0	24.8	37.9
	27-5	21.6	35.1	30.4
Height growth[2]	27-1	44	53	47
	27-4	75	55	52
	27-5	69	71	79
Rust resistance[3]	27-1	44	31	60
	27-4	79	81	86
	27-5	47	39	70

[1] Rooting percentage.

[2] Performance value for height growth obtained from progeny tests conducted by North Carolina State Tree Improvement Cooperative, Raleigh, NC.

[3] Performance values for rust resistance obtained from progeny tests conducted by North Carolina State Tree Improvement Cooperative, Raleigh, NC.

Table 8. Percent of families and clones retained for propagation based on various rooting percentage culling intensities. The culling criteria was applied to the average of the current rooting cycle and all previous rooting cycles.

Hedging Cycle	Percent Root Culling Criteria			
	90	70	50	30
2	33[1]	56	89	89
	6[2]	17	39	68
3	11	33	78	89
	1	9	27	57
4	0	33	78	89
	0	6	22	53
5	0	33	56	89
	0	7	17	50

[1] Percent of families retained.
[2] Percent of clones retained.

Figure 1. Shoot production of juvenile loblolly pine greenhouse hedges by family.

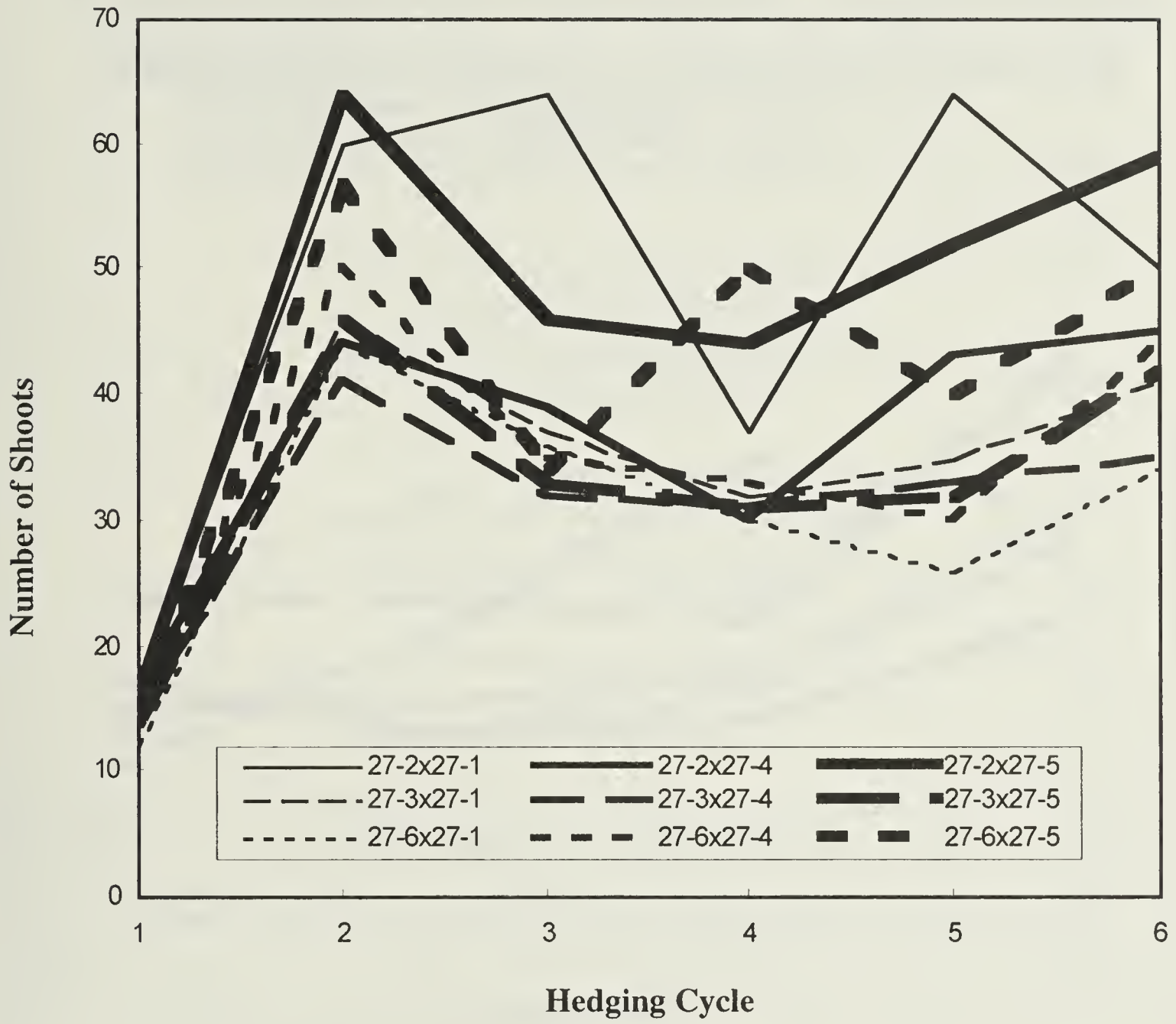
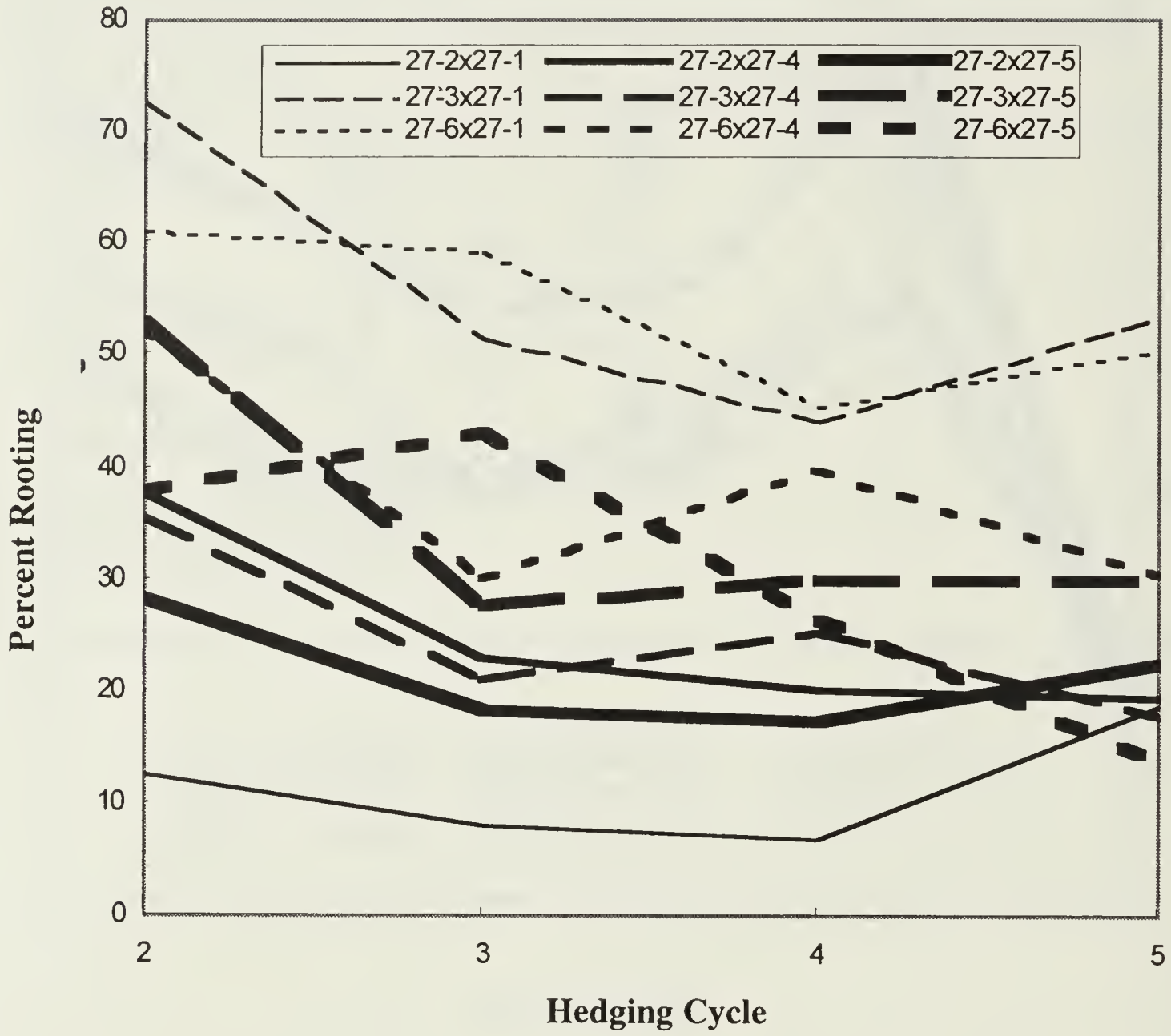


Figure 2. Percent rooting of juvenile loblolly pine cuttings by family.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 15-22

received 1/30/98
accepted 8/2098

Allopatric Spore Ratio Variation in *Leucoagaricus hortensis* (Agaricales, Basidiomycetes), a Species New to Illinois

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ABSTRACT

Basidiospores from two populations of *Leucoagaricus hortensis*, one from Florida and the other from Illinois, were compared as to their average width relative to length. Statistical analysis demonstrated a significant difference between the two populations. Spores from the Illinois locale tended to be proportionately broader than those from Florida. Considering the climatic contrast between these two locales, this difference may reflect an adaptation to environmental factors, such as winter desiccation and cold. This is the first report of this species from Illinois.

INTRODUCTION

Basidiospore length, width, and length/width ratio are among the important microscopic features used for taxonomic identification of basidiomycetes (Singer, 1986). Because variation occurs between individuals and populations, however, problems of systematic assessment sometimes arise. The present study examines the degree and manner of such variation between two populations of *Leucoagaricus hortensis* (Murrill) Pegler, one from Illinois and the other from Florida.

Leucoagaricus hortensis is a saprobic agaric typically found in pasture habitats of warmer latitudes, sometimes occurring directly on manure of herbivorous livestock such as cattle and horses (Akers, 1997). Its basidiospores are ellipsoidal to ovoid in shape, and measure 7.3-13.5 x 5.8-8.5 µm (Akers, 1997). Originally described from Alabama by Murrill (1914), it was later described from Florida by the same author as three new species, *Lepiota humei*, *L. mammillata*, and *L. subfulvidisca* (Murrill, 1943; Akers and Sundberg, 1997). Since then it has been reported from the Caribbean (Dennis, 1952; Pegler, 1983; Rodriguez Gallart, 1990), Colombia (Franco, 1994), Texas (Metzler and

Metzler, 1992), and Hawaii (Don E. Hemmes, pers. comm.). In 1996, a collection was made in Jackson County, Illinois (SIUC Akers 96/9-25/001). This was the first collection of this species in the state, and apparently represents the northern limit of its known distribution.

In agaric species, sexual reproduction occurs when fertile, haploid hyphae of opposite mating types function as gametes by undergoing somatogamy (Moore-Landecker, 1990). Assuming that fertile hyphae in Illinois would have virtually no chance of mating with their counterparts from Florida because of the distance separating them, specimens from these two locales can be theoretically regarded as representing geographically separate populations (Hartl, 1988). The collection from Illinois thus enabled a study as to whether spore width would vary in relation to length differently between a southern population and a more northern one.

MATERIALS AND METHODS

Spore measurements were made by optical microscopy at 1000X using a calibrated ocular micrometer. For analytic purposes, spore width was designated as the criterion variable (Y). Its regression on two predictor variables (X), length (a continuous variable) and locale (a categorical variable), was studied. The specific goals were to discover (a) whether width could be predicted from length, or locale, or both, (b) whether the relationship of length to width differed between the two populations, and (c) whether there was any interaction between the two X variables. The latter proposition was tested using effect coding to determine the best predictive model. All statistical analyses were conducted using SAS (1989). Statistical significance was tested for by calculation of the F ratio, which is interpreted from a table of critical values dependent upon degrees of freedom, defined as n - 1. This type of test thus takes sample size into account as part of the calculation of statistical significance, in effect alleviating theoretical concern about whether a sample size is large enough to warrant the conclusions drawn (Hinkle et al., 1994).

Spore measurement data for the Illinois population were obtained by random sampling of spores from a lamella of the Illinois collection, which consisted of three basidiomata fruiting within several centimeters of each other. Six collections were used to represent the Florida population. One of these collections (SIUC WJS VIII-10-85-B2) was obtained by one of the authors (WJS) in 1985 at the University of Florida horticultural farm, six miles NW of Gainesville. Another (FLAS F 55643) was collected in 1990 by another of the authors (BPA) in Hague, 10 miles N of Gainesville. The other four Florida collections (FLAS F 9656, F 9697, F 18056, and F 19496) date from 1927 to 1938, and came from various sites in and around Gainesville. Site locations within Alachua county are presented in Fig. 1. Florida collections were chosen from different sites in Alachua County to ensure that different genets were sampled, thus allowing for variation at an individual level to yield a set of data reflecting characteristics of the population as a whole. Collections were selected from a population within a single county, i.e., a region small enough that hyphae from one might reasonably be able to mate with those from any of the others. The Illinois population was represented by the single collection available for study. Multiple single-population collections from Florida were utilized to generate a well rounded set of data on the population.

Another potential confounding factor considered was the likelihood that within a single collection, longer spores might tend to be proportionately narrower or broader on average than shorter spores. If this were the case, analytic error could result from spores of one data set having length values different from those of the other (Pedhazur, 1982). To control for this possibility, spore lengths were carefully equilibrated. For each spore measured from Illinois, one of equal length was selected from the Florida collections. This served to enhance the statistical validity of the comparison between the two populations. A total of 30 spores, 15 from each population, constituted the sample size.

This study thus involved the use of two predictor variables, one continuous and the other categorical with two levels, including study of intervariable interaction. The level of significance (α) was set at 0.05, establishing a 95% degree of confidence for the results. The hypothesis proposed that regression of spore width on length would vary between the two populations.

RESULTS

Spore width in relation to length differed significantly between the two populations. Collections from Florida displayed a mean width of 6.4533 µm, a range of 5.5 to 7.7 µm, a standard deviation of 0.5927, and a 0.68193 correlation of length with width. The Illinois collection displayed a mean width of 7.0867 µm, a range of 6.5 to 8.0 µm, a standard deviation of 0.4704, and a 0.70552 correlation of length with width.

Full model correlation analysis indicated high overall significance ($p < 0.0001$), with length as the only significant single predictor ($p < 0.0001$). When the effect coded interactive term was removed, however, locale also became a significant predictor ($p < 0.0002$). These results are summarized below in Tables 1 and 2.

Analysis was also conducted to obtain coefficients of regression. The overall equation obtained for the full model was:

$$Y' = 3.022 + 0.384(\text{Length}) - 0.685(E) + 0.038(E*\text{Length})$$

This model yielded separate regression equations for each locale:

Florida: $Y' = 2.337 + 0.422(\text{Length})$
Illinois: $Y' = 3.707 + 0.346(\text{Length})$

Because of the nonsignificance of the interaction between the two predictors, regression analysis testing only the main effects was conducted. The overall regression equation resulting from this revised model was:

$$Y' = 3.022 + 0.384(\text{Length}) - 0.317(E)$$

This generated revised regression equations for each of the two populations:

Florida: $Y' = 2.706 + 0.384(\text{Length})$
Illinois: $Y' = 3.339 + 0.384(\text{Length})$

To determine the best predictive model, each of the two X variables by itself was treated to regression analysis. A simple analysis using only length indicated significance ($p <$

0.0007), which was slightly diminished from the two-predictor model. The associated regression equation obtained was:

$$Y' = 3.022 + 0.384(\text{Length})$$

Tested by itself, locale was still significant ($p < 0.0031$), but again to a diminished degree. The regression equation resulting from this model was:

$$Y' = 6.77 - 0.317(E)$$

For the two locales, separate regression equations were obtained:

Florida (Locale 1): $Y' = 6.453$
Illinois (Locale 2): $Y' = 7.087$

These two predicted values correspond exactly to those obtained for average width by correlation analysis. Analysis thus showed that the best predictive model was the one incorporating main effects only. The regression equations for the separate locales from that model were used to calculate predicted width values (Y') for minimum and maximum spore lengths of 8.6 and 12.7 µm, respectively. The values this procedure generated were 6.0084 and 7.5828 for Florida; and 6.6414 and 8.2158 for Illinois. These data points were plotted to scale and their corresponding regression lines drawn (Fig. 2).

DISCUSSION

Considering the climatic difference between Illinois and Florida, the tendency toward a lower length/width spore ratio in the more northern population of *Leucoagaricus hortensis* is interesting. One question it raises is whether other basidiomycete species are typified by such variation in spore ratio between geographically separated populations. If so, a further question would arise of whether this variation is random, such that a northern population of some other species might have spores which are narrower on average than those from a southern population. This would be the reverse of the case observed here for *L. hortensis*. Equally compelling, however, is the possibility of patterning in such variation, with northern populations in general tending to exhibit spores that are proportionately broader, per unit length, than southern ones. If this were the case, an explanation for such patterning might be found in the climatic differences between northern and southern latitudes. For example, greater width in relation to length might confer some greater degree of resistance to desiccation and cold in a climate with comparatively harsh winters. This possible adaptive significance could thus reflect an environmental selection factor. Further investigation will be necessary to test this hypothesis.

CONCLUSION

Length and locale are both significant predictors of basidiospore width in *Leucoagaricus hortensis*. Length is the better single predictor, but the best model uses both variables, and is able to account for 62% of the variance in spore width. Based on this model, the odds are less than 2 in 10,000 that the width-per-unit-length variation observed here between Illinois spores and Florida spores would occur by random chance. Analysis thus supported the hypothesis that there would be a significant difference between populations in regard to spore ratio. This difference is considered here as an allopatric variation, because of its statistically significant association with populations in different geographic

regions. An interesting future direction for research is the question of whether *L. hortensis* is unique in this regard or whether other species of basidiomycetes display similar variation between northern and southern populations. In the meantime, a cautionary note is sounded regarding the use of average basidiospore ratio in taxonomic identification of agarics, because of demonstrated variability of this character between populations of the species studied here.

ACKNOWLEDGMENTS

The authors would like to thank James Kimbrough, curator of the fungal collections of the University of Florida herbarium (FLAS), for loaning specimens of *Leucoagaricus hortensis* for study. Also, David Gibson, Keith Fessel and Patricia Woelkhe are thanked for helpful comments offered about this research.

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Figure 1. Florida collection sites of *Leucoagaricus hortensis*.

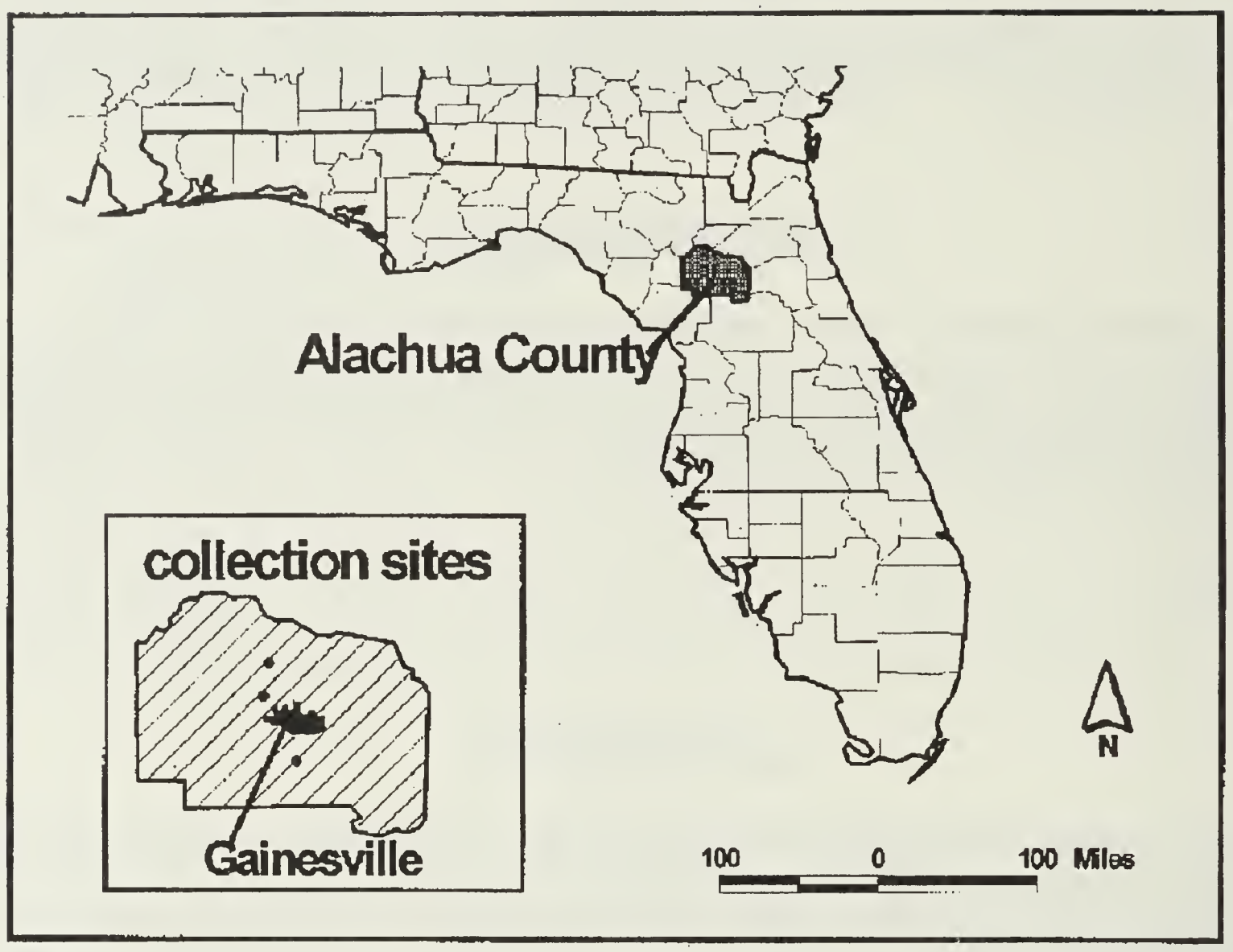


Table 1. Summary table for full model using Proc GLM (SAS 1989).

Dependent variable = Spore width

SOURCE	df	SS	MS	F-value	p-value
Regression	3	6.837	2.279	14.15	<0.0001
Residual	26	4.186	0.161		
Total	29	11.023			

R-squared = 0.62

SOURCE	df	Type III SS	F-value	p-value
Length	1	3.792	23.55	<0.0001
Locale	1	0.125	0.78	<0.3854
Length*Locale	1	0.037	0.23	<0.6375

Table 2. Summary table for revised model using Proc GLM (SAS 1989).

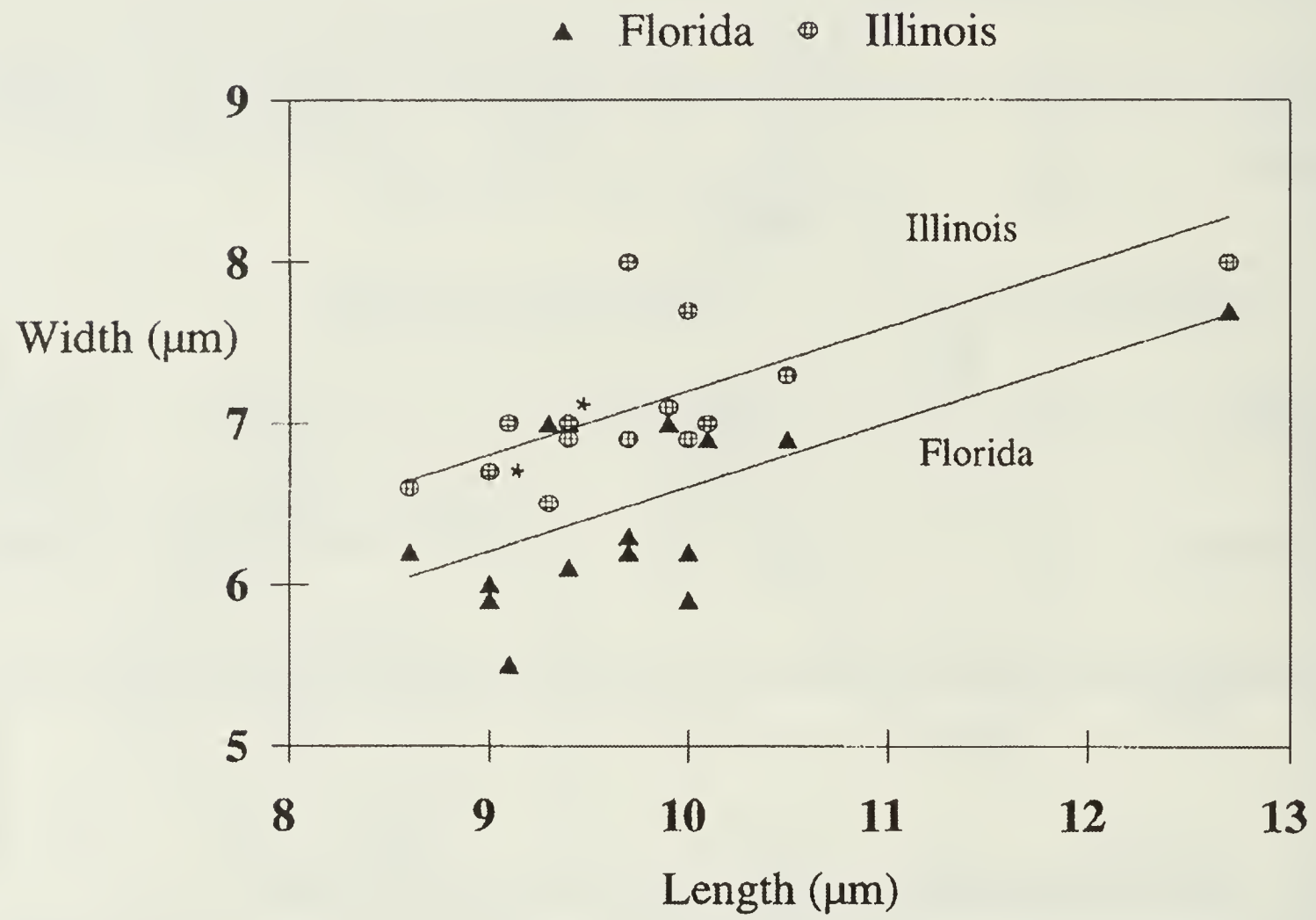
Dependent variable = Spore width

SOURCE	df	SS	MS	F-value	p-value
Regression	2	6.800	3.4	21.74	<0.0001
Residual	27	4.222	0.156		
Total	29	11.023			

R-squared = 0.62

SOURCE	df	Type III SS	F-value	p-value
Length	1	3.792	24.24	<0.0001
Locale	1	3.008	19.23	<0.0002

Figure. 2. Regression lines of spore width x length for two populations of *Leucoagaricus hortensis* (*represents two data points).



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 23-31

received 1/30/98
accepted 6/9/98

Elevated Atmospheric Carbon Dioxide Alters the Effects of Allelochemicals Produced by Tall Fescue on Alfalfa Seedlings

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ABSTRACT

Aqueous extracts of tall fescue *(Festuca arundinacea* Schreber) leaf tissues were applied to alfalfa (*Medicago sativa* L.) seedlings grown under ambient or double ambient atmospheric CO_2 (approximately 700 $\mu L\ L^{-1}$). Exposure to elevated CO_2 for 2 weeks stimulated the growth of alfalfa seedlings. More importantly, however, there was a significant interaction between the extract concentration and the CO_2 level on plant height and root dry weight, indicating that extract concentrations which were stimulatory under ambient conditions, had little effect or became slightly toxic at the higher CO_2 level. This result is important given the currently increasing level of CO_2 and the unknown effect it will have on plants exposed to allelochemicals. Our data demonstrated that elevated levels of atmospheric CO_2 enhanced the phytotoxicity of tall fescue in alfalfa.

INTRODUCTION

Several studies have reported on the altered effect of allelochemicals (Toai and Linscott, 1979; Stowe and Osborn, 1980) and allelochemical production (Tang et al., 1995; Sterling et al., 1987) by environmental stress. Normally, the amount or toxicity of allelochemicals are increased in the producing plant, and the receiving species becomes more intolerant with stress. Despite the demonstrated effects of environmental stress on allelopathy, little work has been done to study the effect of elevated atmospheric CO_2.

Since 1750, atmospheric CO_2 concentration has risen from 280 $\mu L\ L^{-1}$ to 345 $\mu L\ L^{-1}$ (Neftel et al., 1985). As the trend continues, the importance of determining the consequences to plant growth increases. Several authors have found varying effects of ele-

vated CO_2 on the production of secondary metabolites (Fajer et al., 1992; Stuhlfauth et al., 1987). However, no predictions regarding the ecological role of allelochemicals can be made until the effect on receiving species is determined.

The allelopathic potential of the forage grass tall fescue has been previously demonstrated (Chung and Miller, 1995; Smith and Martin, 1994; Peters and Mohammed Zam, 1981). Identification of inhibitory substances by gas-liquid chromatography of the active anion fraction of aqueous extracts detected eight organic acids and four unknowns. Of these, lactic and succinic acid were the most inhibitory to birdsfoot trefoil (*Lotus corniculatus* L.) seedlings (Luu et al., 1989). Legumes, such as alfalfa, are commonly used as target species because of the difficulty in establishing legumes in tall fescue pastures (Smith and Martin, 1994). The objective of this study was to ascertain the effect of elevated CO_2 on alfalfa, a species known to be sensitive to allelochemicals produced by tall fescue (Smith and Martin, 1994; Chung and Miller, 1995).

MATERIALS AND METHODS

We obtained aqueous extracts from leaf tissue clipped from mature tall fescue ('Kentucky 31') plants which had been grown in a greenhouse. These plants were all infected by the endophyte *Neotyphoium coenophialum* (Morgan-Jones & W. Gams) Glenn, Bacon & Hanlin. The clippings were freeze-dried and ground in a Wiley mill with a 40-mesh screen. We used three extract concentrations: 5 g/L, 3 g/L, and 1 g/L dried and ground tall fescue leaves in distilled water. Concentrations were based on an estimation by Smith and Martin (1994) that aqueous extracts from tall fescue leaf tissue of 4.4 (±0.3) g dry wt./L would result in 50% inhibition of the growth of germinating alfalfa seed. Ten, 6, or 2 grams of dried material were placed in 200 mL of distilled water, and allowed to stand for 48 to 72 hours in the laboratory at room temperature. We then filtered the extracts with Whatman no. 2 paper and diluted them to 2 L. The extract was kept up to 6 days in the laboratory and the procedure was repeated as more extract was needed (usually every four days).

Two to three seeds of alfalfa (*M. sativa* 'WL-322 HQ') were planted in each of eighty 10.2 cm diameter pots filled with a soilless growth media consisting of two parts peat moss, one part vermiculite, and one part perlite by volume. After 6 days, we thinned the alfalfa seedlings to the largest plant per pot.

Twenty open-topped CO_2 chambers were constructed according to the design of Ashenden et al. (1992) and placed in a field at the Touch of Nature Environmental Center, Carbondale, IL. The experiment took place in July 1996. Ambient air was pumped into ten of the chambers, and the other ten chambers were maintained at 700 $\mu L\ L^{-1}$. We placed four alfalfa plants in each chamber; a control treated with distilled water and one seedling each treated with one of the three extracts (1 g/L, 3g/L, and 5 g/L). Seedlings were treated to saturation with extract/water every other day and all plants were fertilized on alternate days with half strength 20-10-20 Peters® professional general purpose fertilizer (Scotts-Sierra Horticultural Products Company, Marysville, OH). Alfalfa plants received supplemental watering from rain, or twice daily as needed to avoid water stress. After 1 week, we measured shoot height of the plants in the chambers and re-randomized pot placement. After 2 weeks, we determined shoot height and leaf number in the cham-

bers and removed the plants. We rinsed the roots and measured their length. Plants were dried at 57° C, cut into root and shoot, and weighed.

Height data were analyzed with a split-plot design using SAS (SAS Institute, Cary, NC). CO_2 concentration and block were the whole plot factors and extract concentration and time were the subplot factors. The twenty chambers were arranged so that one fan ventilated four chambers: two ambient and two elevated. Within a block, each ambient chamber was paired with an elevated chamber. This design gave us five blocks of four chambers each. Leaf number, root length, and dry weight data were analyzed in SAS using separate non-parametric two-way ANOVAs (treatments were extract concentration and CO_2 level) on ranks. Plants were subject to insect herbivory while in the chambers. The data for six plants with severe herbivore damage were not used in the analysis. Eight plants included in the data set had visible leaf damage. There was no apparent pattern of damage either between chambers or among extract concentrations.

RESULTS

There was a significant interaction between extract concentration and atmospheric CO_2 level on the height of the alfalfa seedlings (DF=3/48, F=3.09, P=0.04) (Figure 1). Under ambient atmospheric CO_2, aqueous tall fescue extracts stimulated growth of alfalfa seedlings. However, under elevated CO_2 there was no apparent affect on the height of alfalfa stems at the concentrations studied. As expected, time had the greatest influence on height (DF=1/18, F=947.82, P=0.0001) but did not interact with either CO_2 level or extract concentration. Remaining treatments and interactions were not significant (Table 1).

Other measurements on the alfalfa seedlings taken in addition to height at the end of the experiment demonstrated differential sensitivity towards the treatments (Table 2). Root biomass displayed an interaction effect similar to, but stronger than, that of height (DF=3/48, F=3.52, P=.02) (Figure 2). Under ambient CO_2 increasing extract concentration stimulated root growth. However, root biomass was greater under elevated CO_2 and not affected by extract concentration except at the highest concentration at which root biomass was decreased. Root length was the only measurement to exhibit a significant effect of extract concentration independent of CO_2 level (DF=3, F=3.00, P=.04; data not shown). Leaf number and shoot biomass were significantly affected by CO_2 level, but not extract concentration, with larger values under elevated CO_2 (Table 2).

DISCUSSION

The allelochemical effects of tall fescue extract on alfalfa seedlings reported here are not as dramatic as those observed by Smith and Martin (1994). However this variation could be attributed to the developmental stage of seedlings at the time of extract application (germinating seeds in their study vs. three week seedlings in ours) or varying environmental conditions (laboratory environment in their study vs. field conditions in our study). Also, allelopathic potential has been shown to vary between tall fescue genotypes (Peters and Mohammed Zam, 1981). Smith and Martin (1994) did not report which genotype or cultivar of tall fescue they used and it is not known whether their plants were endophyte infected as were ours. Differences have been shown among cultivars of cotton

and soybeans in their ability to cope with allelochemicals (Hicks et al., 1989; Herrin et al., 1986), but alfalfa has not been tested for a similar response. Finally, the endophytic fungus of tall fescue which was included in this study, may produce alkaloids or other chemicals which could alter the effect of the normally occurring allelochemicals produced by non-endophyte infected tall fescue.

The nature of the interaction between extract concentration and CO_2 level (Figure 1) was unexpected considering CO_2 often stimulates many of the mechanisms considered as possible means of inhibition by allelochemicals. Elevated CO_2 often increases photosynthesis of C3 plants, at least temporarily (Körner, 1993). Suppressed photosynthesis may be a mechanism of allelochemical growth inhibition (Bhomik and Doll, 1984). Bhomik and Doll (1984) demonstrated decreased nutrient uptake/accumulation in some species exposed to allelochemicals. Conversely, increased CO_2 aids in nutrient use efficiency (Luxmoore et al., 1986; Norby et al., 1986). In general, dark respiration increases with increased CO_2 levels, and photorespiration decreases (Körner, 1993). Reaction of respiration to allelochemicals varies between studies, but most often respiration is stimulated, especially in mature tissue as opposed to germinating seeds and juvenile tissue (Weaver and Klarich, 1977; McCahon et al., 1973).

The significant change in root length from extract treatments is consistent with the results of Chung and Miller (1995) who found radicle length in alfalfa to be more sensitive to allelochemicals than hypocotyl length. The significant effects of elevated CO_2 on leaf number, shoot weight, and root weight are consistent with the stimulatory effects of increasing carbon dioxide on growth demonstrated by Macdowall (1983) with alfalfa.

This study introduces a new and important effect of elevated atmospheric CO_2 levels. If rising atmospheric CO_2 levels affect the response of a plant to allelochemicals then significant consequences could be seen in vegetational patterning and agro-ecosystems. Just as elevated CO_2 may affect evolution in a community, although indirectly (Bazzaz et al., 1995); so have allelochemicals been shown to induce genetic diversity (Lawrence et al., 1991) thereby making predictions regarding the long term effects of a CO_2 and allelochemical interaction in nature difficult and uncertain.

ACKNOWLEDGMENTS

Special appreciation is owed to Dr. Richard Dado, Dr. Henry Fribourg, Dan Gustafson, Dr. Donald Tindall, Dr. Jeff Weidenhammer, Peggy Wilken, and Tracy Applebee for their sacrifice of time and materials. This research was funded, in part, by a grant from the Illinois Council for Food and Agricultural Research to Jonathan A. Newman and David J. Gibson.

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Table 1. Split-plot analysis of height. The whole plot factors are identified in parentheses. F-values with * are significant at $\alpha \leq 0.05$, ** are significant at $\alpha \leq 0.01$. The interaction between CO_2 and extract concentration is depicted in Figure 1.

Source	DF	MS	F Value
Block	4	11.86	
CO_2	1	49.70	3.83
Chamber (CO_2, Block)	14	12.97	
Extract	3	4.04	0.38
CO_2 x Extract	3	32.61	*3.09
Chamber (CO_2, Block) Extract	48	10.56	
Time	1	5043.21	**947.82
Time x CO_2	1	19.08	3.59
Chamber (CO_2, Block) Time	18	5.32	
Extract x Time	3	0.80	0.15
Extract x Time x CO_2	3	8.12	1.56
Chamber (CO2, Block) Extract x Time	48	5.20	

Table 2. Non-parametric two-way ANOVAs. The whole plot factors are identified in parentheses. F-Values with * are significant at $\alpha \leq 0.05$, ** are significant at $\alpha \leq 0.01$.

		Leaf Number		Root Length		Shoot Biomass		Root Biomass	
Source	DF	MS	F Value	MS	F Value	MS	F Value	MS	F Value
Block	4	891.82		507.73		746.47		1251.96	
CO_2	1	7198.49	**12.95	102.42	0.23	7174.89	**16.00	10110.95	**24.65
Chamber(CO_2, Block)	14	555.97		451.09		448.56		410.23	
Extract	3	45.93	0.15	1341.01	*3.00	120.50	0.38	118.03	0.56
Extract x CO_2	3	284.91	0.93	361.01	0.81	408.44	1.28	738.58	*3.52
Chamber(CO_2, Block) Extract	48	306.63		447.38		319.73		209.96	

Figure 1. The interaction of atmospheric CO_2 levels and concentration of aqueous extracts from tall fescue leaf tissue upon height (mean ± S.E.) of alfalfa seedlings (P=0.036).

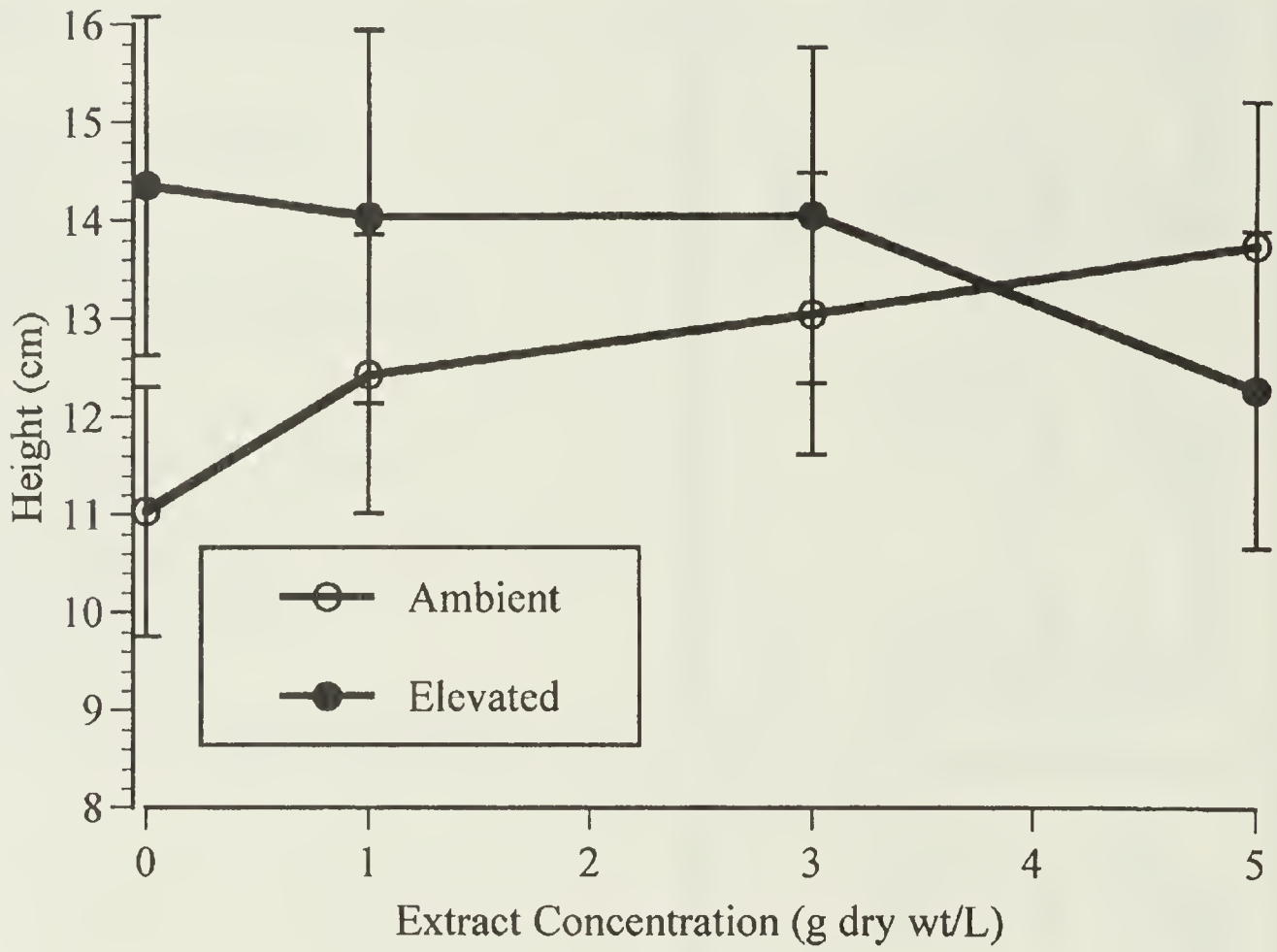
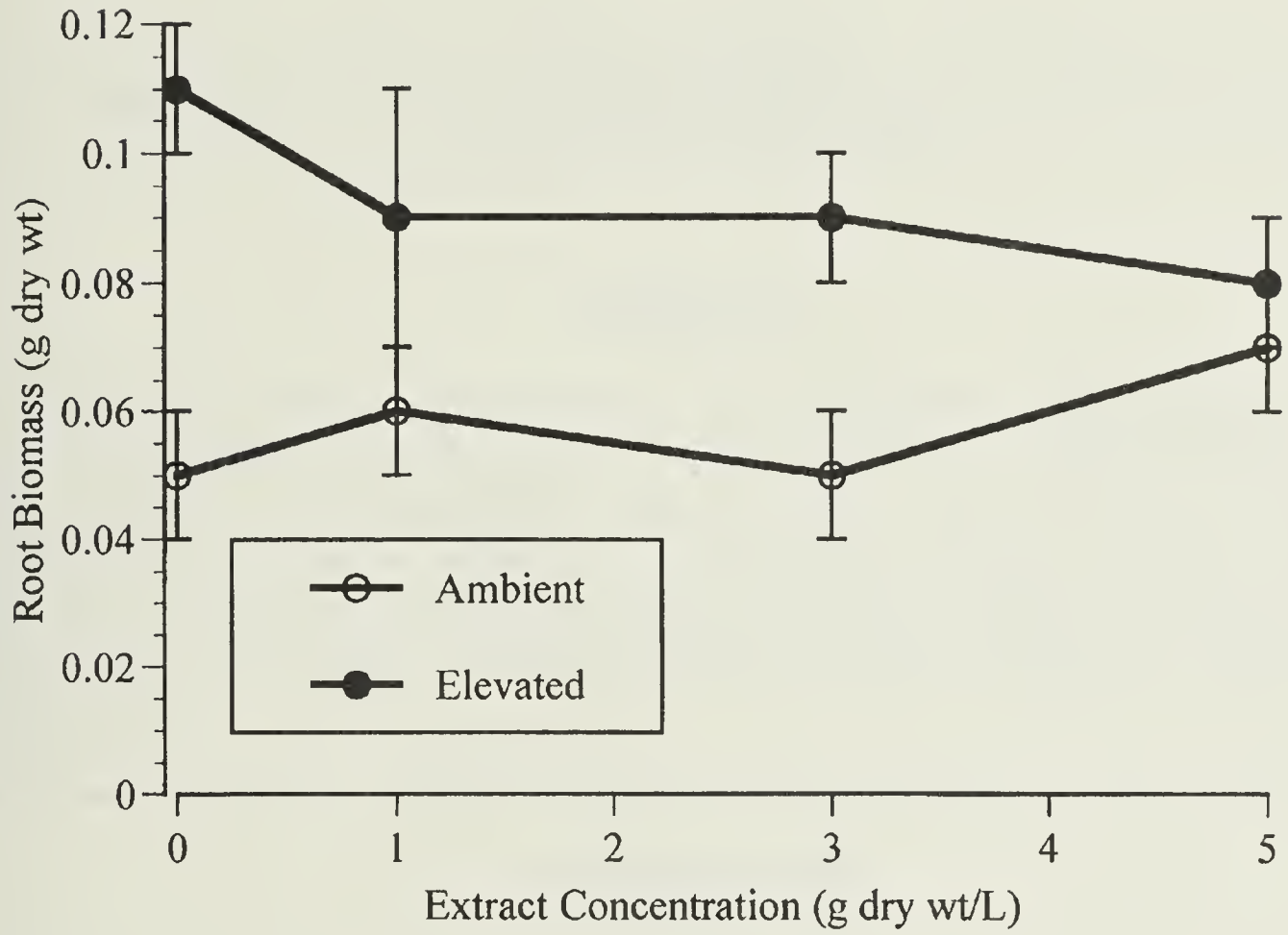


Figure 2. The interaction of atmospheric CO_2 levels and concentration of aqueous extracts from tall fescue leaf tissue upon root biomass (mean ± 1 S.E.) of alfalfa seedlings (P=0.022).



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 33-36

received 7/31/98
accepted 11/5/98

Notes on some Naturalized Woody Plant Species New to Illinois

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ABSTRACT

The first known naturalized occurrences of *Acer campestre* L., *Acer palmatum* Thunb., *Magnolia grandiflora* L., *Phyllostachys aureus* (Carr.) Riv., and *Viburnum dilatatum* Thunb. in Illinois are reported from Jackson County. *Ilex opaca* Ait., a native shrub thought to be extirpated, is reported as an adventive member of the flora. These six species have become naturalized from original plantings at Marberry Arboretum and/or Southern Illinois University at Carbondale and several have potential to become future invasive species.

INTRODUCTION

Ebinger and McClain (1998) recently reported five non-native woody species that are currently naturalized in Illinois and that have the potential to become future management problems in natural areas. There is great concern about the spread of invasive non-native plant species (Harty 1986), since non-native taxa constitute approximately 30% of all plant species known in Illinois (Mohlenbrock 1986). For example, Swink and Wilhelm (1994) reported that approximately 35% of the vascular flora and 95% of the vegetative cover of the Chicago Region is comprised of non-native species. The predominance of invasive plant species in Illinois' landscape has made natural area management, restoration, and conservation of our native biodiversity very difficult (Ebinger 1983). This paper reports six adventive woody plant species from Marberry Arboretum and the campus of Southern Illinois University at Carbondale, five of which are new to Illinois' flora, and discusses their potential as management concerns. These six taxa are not only spreading within the areas in which they were originally planted, but they are spreading into adjacent natural and cultural communities. Nomenclature for associated species follows Mohlenbrock (1986). Voucher specimens have been deposited at the Illinois Natural History Survey Herbarium (ILLS).

RESULTS AND DISCUSSION

Acer campestre L. (Hedge maple, Aceraceae): Jackson Co., IL, locally abundant subcanopy trees with numerous shrubs and seedlings in dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11349.

Hedge maple is a shrub or tree from 12 to 25 m tall native to Europe and west Asia. Distinctive characteristics of this species include three to five lobed leaves which are glabrous above and pubescent below, milky latex when the petiole is broken, greenish flowers in pubescent corymbs, and horizontally spreading schizocarps (Rehder 1940; Bailey 1949). Associated species included *Botrychium virginianum*, *Euonymus alata*, *E. fortunei*, *Hedera helix*, *Quercus alba*, *Q. velutina*, *Phryma leptostachya*, *Phyllostachys aureus*, *Rehsonia sinensis*, and *Sanicula canadensis*. *Acer campestre* has the potential to become a management concern due to its abundant production of wind-dispersed fruits and tolerance of shaded habitats (Groves and Burdon 1986; McKnight 1993; Webb and Kaunzinger 1993).

Acer palmatum Thunb. (Japanese maple, Aceraceae): Jackson Co., IL, locally abundant in dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11343.

Japanese maple is a shrub or small tree to 10 m tall originally native to Japan and Korea. This species is distinguished by its glabrous, deeply five to nine parted leaves and purple flowers in erect, glabrous corymbs (Rehder 1940; Bailey 1949). Associated species included *Acer ginnala*, *Cercis candensis*, *Cornus florida*, *Elaeagnus umbellata*, *Euonymus fortunei*, *Hedera helix*, *Lonicera maackii*, *Parthenocissus quinquefolia*, *Rudbeckia hirta*, *Sanicula canadensis*, *Toxicodendron radicans*, and *Vinca minor*. *Acer palmatum* has the potential to become a management concern in dry-mesic and mesic upland forests due to its abundant production of wind-dispersed fruits and tolerance of shaded habitats (Groves and Burdon 1986; McKnight 1993; Webb and Kaunzinger 1993).

Ilex opaca Ait. (American holly, Aquifoliaceae): Jackson Co., IL, frequent in understory of pine plantation and dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11344.

This species is a shrub or small tree to 16 m tall native to the eastern United States from Massachusetts south to Florida and west to southeastern Missouri and Texas. American holly is distinguished by its spinose, alternate, evergreen leaves, unisexual and perfect flowers on the same plant, and red berries (Rehder 1940; Bailey 1949; Radford et al. 1968). American holly was considered to be a native plant (Mohlenbrock 1978) that is now extirpated in Illinois and was not listed as threatened or endangered by Herkert (1991). One modern collection that represents the extirpated native population of American holly from Union County was present in the Southern Illinois University at Carbondale Herbarium (Minckler, s.n. 1954, Ramberger Hollow near Alto Pass, SIU). Naturalized American holly is frequent at Marberry Arboretum in shaded upland habitats with *Acer saccharum*, *Botrychium virginianum*, *Euonymus fortunei*, *Galium aparine*, *Helianthus divaricatus*, *Ligustrum vulgare*, *Lonicera japonica*, *L. maackii*, *Monarda bradburiana*, *Pinus echinata*, *Polystichum acrostichoides*, *Prunus avium*, *Rehsonia sinensis*, and *Viburnum dilatatum*. This species is also frequent in disturbed dry-mesic upland and mesic floodplain forests on the campus of Southern Illinois University at Carbondale and has the potential to become a management concern due to its tolerance of shaded habitats and abundant production of animal-dispersed fruits (Groves and Burdon 1986; Whelan and Dilger 1992; McKnight 1993).

Magnolia grandiflora L. (Southern magnolia, Magnoliaceae): Jackson Co., IL, occasional shrubs and seedlings in pine plantation and dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11346.

Southern magnolia is a large tree up to 40 m tall native to the coastal plain of the southeastern United States from North Carolina to Florida and westward to Texas, but it has been extensively planted elsewhere outside its native range (Rehder 1940; Bailey 1949; Radford et al. 1968). This taxon is the only *Magnolia* native to the United States which has evergreen leaves. Distinguishing characteristics of this taxon include leaves which are dark green and shiny above and covered with reddish-brown trichomes below, flowers which are white, fragrant, and are produced between June-August, and seeds which are red, arillate, bird-dispersed, and formed within a conical aggregate of follicles (Rehder 1940, Radford et al. 1968). *M. grandiflora* was also observed as seedlings in dry-mesic upland forest along the Thompson Lake path and in Thompson Woods on the campus of Southern Illinois University at Carbondale. Associated taxa included *Cornus florida*, *Hedera helix*, *Helianthus divaricatus*, *Ilex opaca*, *Pinus echinata*, *Prunus avium*, *Rehsonia sinensis*, and *Toxicodendron radicans*. This species does not appear to pose a management concern though it may become a more frequent adventive member of our flora due to its bird-dispersed seeds (Groves and Burdon 1986).

Phyllostachys aureus (Carr.) Riv. (Giant yellow bamboo, Poaceae): Jackson Co., IL, vegetatively spreading from old homesite into dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11347.

This woody grass grows to 8 m tall, is native to China and Japan, and is the most commonly planted ornamental *Phyllostachys* in the southeastern United States (Rehder 1940). Giant yellow bamboo is distinguished by its 3-6 m tall yellow culms, small lanceolate leaves, and stem sheaths with no to few small, purple spots (Rehder 1940; Bailey 1949; Radford et al. 1968). The specific epithet is also spelled *aurea*. This taxon is not a true sexually reproducing member of our flora, although it can remain persistent from cultivation for many years and vegetatively spread to form enormous colonies (Bailey 1949; Radford et al. 1968). It is encountered around old homesites in southern Illinois (pers. obs.). Associated taxa included *Acer campestre*, *A. saccharum*, *Euonymus fortunei*, *Hedera helix*, *Pinus strobus*, *Quercus velutina*, *Rehsonia sinensis*, and *Toxicodendron radicans*. *Phyllostachys aureus* presents a management concern given its fast growth rate, ability to form dense monocultural stands, and tolerance of shaded habitats (Groves and Burdon 1986; McKnight 1993).

Viburnum dilatatum Thunb. (Caprifoliaceae): Jackson Co., IL, frequently escaped into pine plantation and dry-mesic upland forest at Marberry Arboretum in Carbondale along Pleasant Hill Road, 28 June 1998, Basinger 11348.

This east Asian shrub of the honeysuckle family has opposite, rotund to obovate leaves with coarsely dentate margins, rounded to subcordate bases and abruptly short acuminate apices, pilose foliage, stems, and inflorescences, numerous clusters of white flowers in compound cymes, and scarlet drupes (Rehder 1940; Bailey 1949). Associated taxa

included *Acer palmatum, A. saccharum, Botrychium virginianum, Cornus florida, Elaeagnus umbellata, Euonymus alata, E. fortunei, Galium circaezans, Hedera helix, Ilex opaca, Lonicera maackii, Parthenocissus quinquefolia, Phryma leptostachya, Pinus echinata, Prunus avium, Quercus velutina, Rehsonia sinensis,* and *Toxicodendron radicans.* This species has the potential to become a serious invasive plant, given its abundant production of bird-dispersed fruit and tolerance of shaded habitats (Groves and Burdon 1986; Heidorn 1991; Nyboer 1992; Whelan and Dilger 1992; McKnight 1993).

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 37-51

received 5/15/98
accepted 8/25/98

Vascular Flora of Chauncey Marsh Natural Area, Lawrence County, Illinois

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ABSTRACT

The vascular flora of the Chauncey Marsh Natural Area, Lawrence County, Illinois was studied during the 1994 to 1996 growing seasons. A total of 351 taxa were found: five fern and fern-allies, 101 monocots, and 245 dicots. The families with the largest number of taxa include the Poaceae with 48 taxa, the Asteraceae with 33 taxa, and the Cyperaceae with 30 taxa, of which 20 were members of the genus *Carex*. An overstory analysis of the second growth wet-mesic floodplain forest that occurs on the site was also undertaken. In this forest, tree density averaged 353 stems/ha, with an average basal area of 28.5 m^2/ha. *Carya laciniosa* (Michx.) Loud. (kingnut hickory) ranked first with an importance value (IV) of 44.9 (out of 200). Associated species included *Liquidambar styraciflua* L. (sweet gum), *Quercus palustris* Muenchh. (pin oak), *Acer saccharinum* L. (silver maple), and *Ulmus americana* L. (American elm), all with IV's >15.

INTRODUCTION

Chauncey Marsh is an extensive wetland about four miles east of Chauncey, Lawrence County, Illinois. The marsh is located on an old ox-bow of the Embarras River, and is the largest marsh remaining in the Illinois portion of the Wabash River basin. The site contains an outstanding example of marsh and bottomland forest that was typical of this region at the time of European settlement. Elevation is from 130-133 meters above sea level.

Chauncey Marsh is recognized by the Illinois Natural Areas Inventory of White and Madany (1978). It is located in the Chauncey Marsh Natural Area (CMNA) and is a dedicated Nature Preserve. Though subjected to some disturbance, including drainage attempts, the marsh still contains a relatively high diversity of plant and animal life. Ebinger (1982) found 165 taxa of vascular plants growing within the marsh community.

Within the CMNA five major plant communities occur. The cultural communities are represented by prairie plantings, successional fields, croplands, and roadsides. Four natural wetland communities are present: small, scattered shrub swamps, an extensive marsh, an extensive wet-mesic floodplain forest, and a small, wet floodplain forest. The present study was undertaken to document the vascular flora in these plant communities at the

CMNA, and to determine the composition and structure of the extensive wet-mesic floodplain forest.

MATERIALS AND METHODS

Field trips were made to the CMNA at various times in late 1994, every two weeks during the growing season of 1995 and in the summer of 1996. During each trip voucher specimens were collected, habitat data for each taxon were determined, and the plant communities were delineated. A few taxa were not collected as they were endangered or rarely encountered at the site. The material collected was identified and deposited in the herbarium of the Illinois Natural History Survey (ILLS), Champaign, Illinois. Criteria for designating native and non-native taxa followed Fernald (1950), Steyermark (1963), Mohlenbrock (1986), and Gleason and Cronquist (1991).

During the summer of 1995, a 5 ha section (100 m x 500 m) of the wet-mesic floodplain forest was divided into 80 quadrats 25 m on a side. In each quadrat all living and dead-standing tree individuals 6 cm dbh (diameter at breast height, 1.5 meter above the ground) and above were identified and their diameters recorded. From these data the density (stems/ha), basal area (m^2/ha), relative density, relative dominance, importance value (IV), and average diameter (cm) were calculated for each species. The determination of the IV follows the procedure used by McIntosh (1957), and is the sum of the relative density and relative dominance of a given species. The density (stems/ha) of the understory tree species was determined using 80 nested circular plots 0.0001, 0.001, and 0.01 ha in size randomly located along line transects through the study area. Two additional 0.0001 ha circular plots were located 6 m to the east and west of each center. In the 0.0001 ha plots seedlings (<50 cm tall) and all shrubs were counted, in the 0.001 ha circular plots small saplings (>50 cm tall and <2.5 cm dbh) were recorded, and in the 0.01 ha circular plots large saplings (2.5-5.9 cm dbh) were tallied. Nomenclature primarily follows Mohlenbrock (1986).

DESCRIPTION OF THE STUDY AREA

The CMNA is 393 acres (159 ha) in size, and contains the 128 acre (51.8 ha) Chauncey Marsh Nature Preserve (T5N, R12W, S30). Located in northwestern Lawrence County, Illinois, it is in the Bottomland Section of the Wabash Border Division (Schwegman et al. 1973). This section encompasses the bottomland forest, sloughs, marshes, and ox-bow lakes in the floodplain of the Wabash River, the Ohio River, and their major tributaries. The presettlement vegetation of this section was mostly bottomland forest, though wet prairies, marshes, upland forest and shrub swamps were commonly associated with the sloughs and ox-bow lakes.

The forest surveyed is located near the middle of a large tract of timber at the CMNA. This wet-mesic floodplain forest (White and Madany 1978) is situated on a terrace of the Embarras River. This terrace is 131 m above sea level, and about 4 m above the normal flow of the river. The forest is flooded for short periods of time in most years; for about eight days during the spring of 1995, and for two months during the spring of 1996.

Soils of the CMNA are alluvial deposits from the Embarras River. The soil of the wet-mesic floodplain forest is predominately Darwin clay which occurs extensively on the Embarras and Wabash river floodplain and has developed under very poor natural drainage (Fehrenbacher and Odell 1956). The soil of the wet floodplain forest, shrub forest, and marsh is Wabash silty clay which occurs in sloughs and old, partially filled channels. The black, plastic silty clay or clay is formed from fine-textured sediments deposited by slack water and from large accumulations of organic matter (Fehrenbacher and Odell 1956).

The climate of east-central Illinois is continental with cool winters, hot summers, and little or no water deficit at any season of the year (Page 1949, Fehrenbacher et al. 1967, Schwegman et al. 1973). Average annual precipitation is between 101 and 106 cm, with most occurring in the spring. In Palestine, Illinois, just 15 km to the north, the average precipitation is 104.5 cm, with the month of May having the highest rainfall. Mean average temperature in Palestine, Illinois is 12.7°C with the hottest month being July (average of 25.3°C), and the coldest month being January (average of -0.9°C). The average number of frost free days is between 180-190.

RESULTS AND DISCUSSION

Vascular Plant Species Present

The flora of CMNA consists of 351 species and subspecific taxa within 224 genera and 78 families. Of these taxa, 60 (17%) were not native to Illinois, and several taxa planted in a man-made prairie were probably not original components of this natural area. Only one Illinois endangered species, *Silene regia* Sims (royal catchfly) was encountered, and no state threatened species were observed (Herkert 1991). The royal catchfly was planted in the man-made prairie.

As expected, the fern and fern-allies were poorly represented at the CMNA accounting for only five taxa (1% of all taxa). Gymnosperms were not represented, the Angiosperms accounting for the remaining species. Among the Angiosperms, monocots accounted for 101 taxa (29% of all taxa) in 50 genera and 12 families, while dicots made-up the remainder, 245 taxa (70% of all taxa) in 170 genera and 62 families. The largest genera were *Carex* with 20 species and *Polygonum* with 10 species. The largest families were Poaceae (48), Asteraceae (33), Cyperaceae (30), Fabaceae (16), Rosaceae (15), and Polygonaceae (14). For a complete list of taxa see Appendix 1.

Habitat Types Present

Plant communities were designated using the Illinois Natural Areas Inventory (White and Madany 1978). The communities are influenced by periodic flooding of the Embarras River, management practices such as controlled burning and wildlife activities, particularly by white-tailed deer (*Odocoileus virginianus*). Below is a description of each plant community at the CMNA along with the indicator species.

1. Wet-mesic floodplain forests (110.1 ha) occur on poorly drained soils that are periodically flooded during a portion of the growing season and are characterized by a high diversity of deciduous tree species. More than 20 tree species made up the overstory, with *Carya laciniosa*, *Liquidambar styraciflua*, *Quercus palustris*, *Acer saccharinum*,

Ulmus americana, *Q. bicolor*, and *Celtis occidentalis* being the most common. Few woody species occur in the very open understory, although the woody vines *Campsis radicans*, *Toxicodendron radicans*, and *Vitis cinerea* are common. The herbaceous layer is dominated by *Aster lanceolatus*, *A. ontarionis*, *Cryptotaenia canadensis*, *Geum canadense*, *Laportea canadensis*, *Leersia virginica*, *Pilea pumila*, *Sicyos angulatus*, *Solidago gigantea*, and *Zizia aurea.*

2. Wet floodplain forests (9.0 ha) occur in areas frequently flooded during the growing season and are characterized by a low diversity of woody and herbaceous species. Dominant tree species include *Acer saccharinum*, *A. negundo*, *Populus deltoides*, and *Fraxinus pennsylvanica.* Few woody understory trees and shrubs occur in the very open understory, although the woody vines *Toxicodendron radicans* and *Campsis radicans* are common. Herbaceous species include *Boehmeria cylindrica*, *Carex hyalinolepis*, *Elymus virginicus*, *Laportea canadensis*, *Pilea pumila*, and *Ranunculus hispidus* var. *nitidus.*

3. Shrub swamps (0.4 ha) in flooded, usually small depressions, are found scattered around the edge of the bottomland forests and near the open marsh. *Cephalanthus occidentalis* dominates the shrub layer forming dense thickets around the edge and sometimes throughout the depression. The central part of the shrub swamp, which is commonly flooded most of the year, is dominated by a few herbaceous species including *Acalypha rhomboidea*, *Alisma triviale*, *Leersia lenticularis*, *Peltandra virginica*, *Polygonum amphibium*, *P. hydropiperoides*, and *Saururus cernuus.*

4. Emergent marshes (20.8 ha) are characterized by periodic flooding, poorly drained soils and an extremely diverse flora. The few woody species encountered included *Amorpha fruticosa*, *Cephalanthus occidentalis*, *Fraxinus pennsylvanica*, *Populus heterophylla*, *Salix exigua*, and *S. nigra.* The common herbaceous species include *Apios americana*, *Bidens aristosa*, *Hibiscus laevis*, *H. lasiocarpos*, *Polygonum amphibium*, and *P. punctatum.*

5. Cultural communities (18.7 ha) are created and maintained by human disturbance. Two small prairie plantings (1.9 ha) occur in the natural area, while successional fields (0.8 ha) are common along with some croplands (16 ha). A farm road extends through much of the CMNA. The common taxa encountered were introduced and native weedy species with *Achillea millefolium*, *Allium canadense*, *Amaranthus hybridus*, *Conyza canadensis*, *Daucus carota*, *Poa pratensis*, *Setaria faberi*, and *Stellaria media* being the most common.

Within the wet-mesic floodplain terrace forest, tree density averaged 353 stems/ha with a basal area of 28.5 m^2/ha. Tree species diversity was extremely high with 24 tree species present, 20 of which were capable of reaching the canopy (Table 1). Of these species, *Carya laciniosa* ranked first with an IV of 44.9 (possible 200) and accounted for 27% of the density but only 17% of the basal area. This species dominated all smaller diameter classes with 95% of the individuals <50 cm dbh (Table 2). In contrast, *Liquidambar styraciflua* and *Quercus palustris*, which ranked 2nd and 3rd in IV, had high densities in the larger diameter classes and average diameters >45 cm dbh (Table 1). In the future this forest community will probably contain more *C. laciniosa* and less *L. styraciflua* and

Q. palustris. Of the remaining species, individuals of *Acer saccharinum* were fairly well distributed throughout all diameter classes, while most other species dominated the smaller diameter classes. In particular, *Ulmus americana* and *Celtis occidentalis* had 14 or more individuals in the 6-9 cm diameter class, whereas *Quercus bicolor* and *Q. macrocarpa* had relatively high densities in the 6-9 and 10-19 cm diameter classes (5-7 stem/ha) and were also represented in the 80+ cm diameter class. Of the understory species, only *Cercis canadensis* was common with an IV of 4.9 and 15.6 stems/ha. The remaining understory species included *Acer negundo*, *Crataegus mollis*, and *Prunus hortulana*, all with IV's below 1.5 and very low densities.

Tree mortality was not very high, with dead-standing individuals averaging 17.2 stems/ha, having a basal area of 1.36 m^2/ha and an average diameter of 24.4 cm. *Ulmus americana*, with a mortality of 6.8 stems/ha and a basal area of 0.144 m^2/ha, ranked first in dead-standing individuals. *Quercus palustris*, with an average of 2.4 stems/ha, ranked second followed by *Fraxinus pennsylvanica* and *Q. bicolor*. Only a few coppice stems were found, and no cut stumps were observed.

The woody understory was very open; it was usually possible to have a relatively unobstructed view for 50-75 m. Seedling density was 4,044 stems/ha, and most were difficult to find in the dense herbaceous layer. *Carya laciniosa* and *Quercus palustris* seedlings were the most common, but *Fraxinus pennsylvanica*, *Celtis occidentalis*, and *Gleditsia triacanthos* were sometimes encountered (Table 3). The small sapling layer (>50 cm tall, <2.5 cm dbh) was dominated by *Carya laciniosa* (760 stems/ha) and *Fraxinus pennsylvanica* (388 stems/ha). Large saplings (2.5-10.0 cm dbh) were not very common, averaging 221 stems/ha, with *Carya laciniosa*, *Ulmus americana* and *Celtis occidentalis* the most common (Table 3).

The forests at the CMNA are similar to the wet-mesic floodplain forest described by Nÿboer and Ebinger (1976) in Clark County, Illinois. The Clark County forest, located in the northern part of the Embarras River drainage, has many of the same canopy species found at the CMNA. In both forests, *Carya laciniosa* was the leading dominant species with the highest IV and many individuals in the lower diameter classes. Other common components included *Acer saccharinum*, *Celtis occidentalis*, *Gleditsia triacanthos*, *Quercus bicolor*, *Q. macrocarpa*, and *Ulmus americana*. The Clark County site was drier, however, as some upland species were present, such as *Acer saccharum*, *Fraxinus americana*, *Quercus alba*, and *Q. rubra*. At Clark County, *Liquidambar styraciflua* and *Q. palustris*, second and third in IV at CMNA, were absent. Also, the increased importance of *Acer saccharinum* at CMNA (IV of 18.0 with 23.4 stems/ha) far exceeded its importance in the Clark County forest (IV of 5.3 and 4.0 stems/ha), which would be expected as the CMNA is wetter.

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APPENDIX 1

The vascular taxa encountered at the Chauncey Marsh Natural Area are listed below by major groups, Pteridophytes (fern and fern-allies) and Spermatophytes (flowering plants), the latter divided into Monocots and Dicots. The families, genera, and species are alphabetically arranged within each group. Taxa that are introduced in Illinois are indicated by an asterisk (*). After the binomial and authority, the communities where the species were commonly encountered is given (1 = wet-mesic floodplain forest, 2 = wet floodplain forest, 3 = shrub swamp, 4 = emergent marsh, 5 = cultural). Collecting numbers are those of Phillippe (P).

PTERIDOPHYTA

DRYOPTERIDACEAE

Onoclea sensibilis L.; 1; P 26197

ISOETACEAE

Isoëtes melanopoda Gay & Durieu; 1, 5; P 26418

OPHIOGLOSSACEAE

Botrychium dissectum Sprengel; 1; P 26878

Botrychium virginianum (L.) Swartz; 1; P 26146

OSMUNDACEAE

Osmunda regalis L.; 1; P 26307

SPERMATOPHYTA: ANGIOSPERMAE

MONOCOTS

ACORACEAE

**Acorus calamus* L.; 2, 4; P 26391

ALISMACEAE

Alisma triviale Pursh; 3, 4; P 26829

ARACEAE

Arisaema dracontium (L.) Schott; 1; P 26424

Peltandra virginica (L.) Schott; 2, 3, 4; P 26437

COMMELINACEAE

Commelina virginica L.; 1, 4; P 26742

Tradescantia ohiensis Raf.; 5; P 26321

Tradescantia subaspera Ker; 1; P 26410

CYPERACEAE

Carex annectens Bickn.; 5; P 26382

Carex bicknellii Britton; 5; P 26440

Carex brevior (Dewey) Mack.; 5; P 26324

Carex bushii Mack.; 5; P 26335

Carex caroliniana Schwein.; 2; P 26292A

Carex crus-corvi Shuttlew.; 2, 3; P 26445

Carex davisii Schwein. & Torrey; 1, 5; P 26423

Carex festucacea Willd.; 5; P 26323

Carex gracilescens Steudel; 1; P 26201

Carex granularis Willd.; 2; P 26292B

Carex grayi Carey; 1; P 26303

Carex grisea Wahlenb.; 1; P 26304

Carex hyalinolepis Steudel; 1, 2, 4; P 26291

Carex leavenworthii Dewey; 2, 5; P 26322

Carex lupulina Willd.; 1; P 26463

Carex muskingumensis Schwein.; 1, 2, 4; P 26306

Carex squarrosa L.; 1, 2; P 26305

Carex stipata Muhl.; 1, 4; P 26415

Carex typhina Michx.; 1; P 26411

Carex vulpinoidea Michx.; 5; P 26454

Cyperus aristatus Rottboell; 5; P 26738

Cyperus esculentus L.; 5; P 26814

Cyperus odoratus L.; 5; P 26835

Cyperus ovularis (Michx.) Torrey; 4, 5; P 26779

Cyperus strigosus L.; 5; P 26831

Eleocharis obtusa (Willd.) Schultes; 4, 5; P 26737

Scirpus acutus Muhl.; 4; P 26458

Scirpus atrovirens Willd.; 4; P 26453

Scirpus cyperinus (L.) Kunth; 4; P 26752

Scirpus fluviatilis (Torrey) Gray; 4; P 26457

DIOSCOREACEAE

Dioscorea villosa L.; 1, 4; P 26400

IRIDACEAE

Iris virginica L. var. *shrevei* (Small) E. Anderson; 2, 4, 5; P 26338

Sisyrinchium angustifolium Miller; 5; P 26339

JUNCACEAE

Juncus biflorus Ell.; 5; P 26385

Juncus interior Wiegand; 5; P 26828

Juncus tenuis Willd.; 5; P 26431

LEMNACEAE

Lemna minor L.; 3, 4; P 27039

Spirodela polyrhiza (L.) Schleiden; 3, 4; P 27038

LILIACEAE

Allium canadense L.; 5; P 26331

**Allium vineale* L.; 5; P 26442

**Ornithogalum umbellatum* L.; 5; P 26330

Polygonatum biflorum (Walter) Ell.; 1; P 26317

Uvularia sessilifolia L.; 1; P 26316

POACEAE

**Agropyron repens* (L.) Beauv.; 5; P 26442

Agrostis perennans (Walter) Tuck.; 5; P 26806

Alopecurus carolinianus Walter; 5; P 26169

Andropogon gerardii Vitman; 5; P 26788

**Bromus racemosus* L.; 5; P 26446

Chasmanthium latifolium (Michx.) Yates; 1; P 26762

Cinna arundinacea L.; 1, 2; P 26705

**Dactylis glomerata* L.; 5; P 26396

**Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.; 5; P 26805

**Digitaria sanguinalis* (L.) Scopoli; 5; P 26709

Echinochloa muricata (Beauv.) Fern.; 5; P 26735

**Eleusine indica* (L.) Gaertner; 5; P 26733

Elymus canadensis L.; 5; P 26699

Elymus virginicus L.; 1, 2, 4, 5; P 26758

**Eragrostis cilianensis* (All.) Mosher; 5; P 26731

Eragrostis hypnoides (Lam.) BSP; 1; P 26858

Eragrostis pectinacea (Michx.) Nees; 5; P 26736

Festuca obtusa Biehler; 1; P 26318

**Festuca elatior* L.; 5; P 26298

Hordeum pusillum Nutt.; 5; P 26299

Leersia lenticularis Michx.; 1, 2, 3, 4; P 26847

Leersia oryzoides (L.) Swartz; 4; P 26874

Leersia virginica Willd.; 1, 2, 4; P 26769

Leptochloa fascicularis (Lam.) Gray; 5; P 26730

Muhlenbergia bushii Pohl; 1; P 27029

Muhlenbergia frondosa (Poiret) Fern.; 5; P 27041

Panicum clandestinum L.; 5; P 26452

Panicum dichotomiflorum Michx.; 5; P 26838

Panicum lanuginosum Ell. var. *lindheimeri* (Nash) Fern.; 5; P 26381

Panicum rigidulum Nees var. *rigidulum*; 1; P 26842

Panicum virgatum L.; 4, 5; P 26700

Paspalum ciliatifolium Michx.; 5; P 26778

Paspalum fluitans (Ell.) Dunth; 1, 3; P 26865

Paspalum laeve Michx.; 5; P 26725

Paspalum pubiflorum Rupr. *ex* Fourn.; 5; 26780

**Phleum pratense* L.; 5; P 26395

Poa chapmaniana Scribner; 5; P 26168

**Poa pratensis* L.; 5; P 26300

Schizachyrium scoparium (Michx.) Nash; 5; P 26698

**Setaria faberi* Herrm.; 5; P 26710

**Setaria glauca* (L.) Beauv.; 5; P 26815

**Setaria viridis* (L.) Beauv. var. *viridis*; 1, 5; P 26869

**Setaria viridis* (L.) Beauv. var. *major* (Gaudin) Pospichal; 5; P 26836

Sorghastrum nutans (L.) Nash; 5; P 26702

Spartina pectinata Link.; 4; P 26753

Sphenopholis obtusata (Michx.) Scribner var. *major* (Torrey) Erdman; 1; P 26295

Tridens flavus (L.) Hitchcock; 5; P 26785

**Zea mays* L.; 5; P 26804

SMILACACEAE

Smilax ecirrhata Kunth; 1; P 26426

Smilax hispida Muhl.; 1; P 26312

Smilax lasioneuron Hooker; 1; P 26311

DICOTS

ACANTHACEAE

Ruellia strepens L.; 1; P 26761

ACERACEAE

Acer negundo L.; 1, 2; P 26859

Acer rubrum L. var. *drummondii* (Hooker & Arnott) Sargent; 1, 2, 4; P 26151

Acer saccharinum L.; 1, 2, 4; P 26182

AMARANTHACEAE

Amaranthus hybridus L.; 5; P 26839

ANACARDIACEAE

Toxicodendron radicans (L.) Kuntze; 1, 2, 5; P 26409

ANNONACEAE

Asimina triloba (L.) Dunal; 1; P 26187

APIACEAE

Chaerophyllum procumbens (L.) Crantz; 1; P 26186

Cryptotaenia canadensis (L.) DC.; 1, 2; P 26425

**Daucus carota* L.; 5; P 26712

Eryngium yuccifolium Michx.; 5; P 26723

Oxypolis rigidor (L.) Raf.; 1, 3, 4; P 26766

Sanicula canadensis L.; 1, 2; P 26380

Sanicula gregaria Bickn.; 1, 2; P 26192

Sium suave Walter; 2, 3, 4; P 26793

Zizia aurea (L.) Koch; 1, 2, 5; P 26852

APOCYNACEAE

Amsonia tabernaemontana Walter; 2, 4, 5; P 26290

Apocynum sibiricum Jacquin; 4, 5; P 26461

ARISTOLOCHIACEAE

Aristolochia serpentaria L.; 1; P 26383

ASCLEPIADACEAE

Asclepias incarnata L.; 4; P 26751

Asclepias perennis Walter; 2, 3; P 26771

Asclepias syriaca L.; 5; P 26444

Cynanchum laeve (Michx.) Persoon; 5; P 26724

ASTERACEAE

**Achillea millefolium* L.; 5; P 26332

Ambrosia artemisiifolia L.; 5; P 26786

Ambrosia trifida L.; 2, 4, 5; P 26792

Aster lanceolatus Willd.; 1, 2; P 27035

Aster ontarionis Wieg.; 1, 2, 4; P 27037

Aster pilosus Willd.; 5; P 27036

Bidens aristosa (Michx.) Britton; 4, 5; P 26787

Boltonia asteroides (L.) L'Héritier var. *recognita* (Fern. & Griscom) Cronquist; 4, 5; P 26840

Conyza canadensis (L.) Cronquist; 5; P 26837

Coreopsis tripteris L.; 5; 26701

Eclipta prostrata (L.) L.; 3, 4; P 26729

Erigeron annuus (L.) Persoon; 5; P 26403

Erigeron philadelphicus L.; 1, 2; P 26314

Eupatorium coelestinum L.; 1, 4; P 26772

Eupatorium rugosum Houttuyn; 1; P 26704

Eupatorium serotinum Michx.; 1, 4, 5; P 26782

Euthamia graminifolia (L.) Salisbury; 5; P 26822

Helenium autumnale L.; 4, 5; P 26868

Helianthus divaricatus L.; 5; 26706

Helianthus strumosus L.; 5; P 26818

Helianthus tuberosus L.; 5; P 26819

Lactuca canadensis L.; 5; P 26776

**Matricaria matricarioides* (Lessing) Porter; 5; P 26164

Mikania scandens (L.) Willd.; 2; P 26797

Rudbeckia laciniata L.; 1; P 26854

Senecio glabellus Poiret; 1; P 26177

Silphium perfoliatum L.; 1, 4; P 26851

Solidago canadensis L.; 5; P 27033

Solidago gigantea Ait.; 1; P 26872

**Taraxacum officinale* Weber; 5; P 26180

Vernonia fasciculata Michx.; 4; P 26754

Vernonia gigantea (Walter) Trelease; 1; P 26757

**Xanthium strumarium* L. var. *glabratum* (DC.) Cronquist; 5; P 26870

BETULACEAE

Betula nigra L.; 2; P 26871

BIGNONIACEAE

Campsis radicans (L.) Seemann; 1, 2, 5; P 26743

BORAGINACEAE

Myosotis macrosperma Engelm.; 5; P 26325

BRASSICACEAE

**Arabidopsis thaliana* (L.) Heynhold; 5; P 26174

Armoracia lacustris (A. Gray) Al-Shehbaz & V. Bates; 4; P 26456

**Barbarea vulgaris* R. Brown var. *arcuata* (Opiz) Fries; 5; P 26159

**Capsella bursa-pastoris* (L.) Medikus; 1, 5; P 26160

Cardamine bulbosa (Schreber) BSP.; 1; P 26189

Cardamine parviflora L. var. *arenicola* (Britton) O.E. Schultz; 5; P 26175

Draba brachycarpa Nutt.; 5; P 26165

**Draba verna* L.; 5; P 26166

Iodanthus pinnatifidus (Michx.) Steudel; 1; P 26422

Lepidium virginicum L.; 5; P 26161

Sibara virginica (L.) Rollins; 5; P 26171

CAMPANULACEAE

Lobelia cardinalis L.; 1, 2, 4, 5; P 26178

Triodanis perfoliata (L.) Nieuwland var. *perfoliata*; 5; P 26462

CAPRIFOLIACEAE

**Lonicera maackii* (Ruprecht) Maximowicz; 5; P 27275

Sambucus canadensis L.; 1, 2, 4; P 26432

CARYOPHYLLACEAE

**Arenaria serpyllifolia* L.; 5; P 26302

Cerastium nutans Raf.; 5; P 26178

**Cerastium vulgatum* L.; 5; P 26327

**Dianthus armeria* L.; 5; P 26341

Silene regia Sims; 5; not collected

Silene stellata (L.) Ait. f.; 1; P 26703

**Stellaria media* (L.) Cyrillo; 5; P 26179

CELASTRACEAE

Celastrus scandens L.; 1; P 27034

**Euonymus fortunei* (Turczaninow) Handel-Mazzetti; 1; P 26406

CHENOPODIACEAE

Chenopodium album L.; 5; P 26875

CLUSIACEAE

Hypericum mutilum L.; 1, 4, 5; P 26811

Hypericum sphaerocarpum Michx.; 5; P 26455

CONVOLVULACEAE

Calystegia sepium (L.) R. Brown; 5; P 26781

**Convolvulus arvensis* L.; 5; P 26867

**Ipomoea hederacea* (L.) Jacquin; 5; P 26789

Ipomoea lacunosa L.; 1, 2; P 26794

Ipomoea pandurata (L.) G.F.W. Meyer; 5; P 26744

CORNACEAE

Cornus drummondii C.A. Meyer; 5; P 26404

Cornus obliqua Raf.; 1, 2, 5; P 26405

CUCURBITACEAE

Sicyos angulatus L.; 1, 2, 3; P 26863

EBENACEAE

Diospyros virginiana L.; 1; P 26450

EUPHORBIACEAE

Acalypha rhomboidea Raf.; 1, 3; P 26810

Chamaesyce humistrata (Engelm.) Small; 5; P 26834

Chamaesyce maculata (L.) Small; 5; P 26801

Chamaesyce nutans (Lag.) Small; 5; P 26777

Croton glandulosus L. var. *septentrionalis* Mueller-Arg.; 5; P 26820

Euphorbia corollata L.; 5; P 26816

Phyllanthus caroliniensis Walter; 4, 5; P26846

FABACEAE

Amorpha fruticosa L.; 4, 5; P 26451

Amphicarpaea bracteata (L.) Fern.; 1; P 26861

Apios americana Medikus; 2, 4; P 26795

Cercis canadensis L.; 1; P 26193

Chamaecrista fasciculata (Michx.) Greene; 5; P 26716

Desmodium illinoense Gray; 5; P 26717

Desmodium paniculatum (L.) DC.; 5; P 26784

Gleditsia triacanthos L.; 1, 2; P 26309

**Glycine max* (L.) Merrill; 5; P 26833

**Kummerowia stipulacea* (Maximowicz) Makino; 5; P 26715

Lespedeza violacea (L.) Britton; 5; P 26783

**Melilotus alba* Medikus; 5; P 26460

Senna marilandica (L.) Link; 5; P 26746

**Trifolium campestre* Schreber; 5; P 26326

**Trifolium hybridum* L.; 5; P 26707

**Trifolium pratense* L.; 5; P 26297

FAGACEAE

Quercus bicolor Willd.; 1; P 27043

Quercus imbricaria Michx.; 5; P 26154

Quercus macrocarpa Michx.; 1; P 27042

Quercus palustris Muenchh.; 1, 2; P 26767

Quercus shumardii Buckley; 1; P 26856

GERANIACEAE

Geranium carolinianum L.; 5; P 26301

Geranium maculatum L.; 1; P 26155

HALORAGIDACEAE

Proserpinaca palustris L.; 4; P 26833

HAMAMELIDACEAE

Liquidambar styraciflua L.; 1; P 26853

JUGLANDACEAE

Carya cordiformis (Wang.) K. Koch; 1, 5; P 26714

Carya illinoinensis (Wang.) K. Koch; 1; p 26843

Carya laciniosa (Michx.) Loudon; 1; P 26855

Carya tomentosa (Poiret) Nutt.; 1; P 26800

Juglans nigra L.; 1; P 26860

LAMIACEAE

**Lamium amplexicaule* L.; 5; P 26158

**Lamium purpureum* L.; 5; P 26157

Lycopus rubellus Moench.; 1, 2; P 26848
Monarda fistulosa L.; 5; P 26745
Physostegia virginiana (L.) Benth.; 1; P 26877
**Prunella vulgaris* L.; 5; P 26711
Scutellaria lateriflora L.; 1, 4; P 26760
Stachys tenuifolia Willd. var. *tenuifolia*; 1; P 26763
Teucrium canadense L. var. *virginiana* (L.) Eaton; 1, 4, 5; P 26765

LAURACEAE

Lindera benzoin (L.) Blume; 1; P 26185
Sassafras albidum (Nutt.) Nees; 5; P 26153

LYTHRACEAE

Ammannia coccinea Rottboell; 4, 5; P 26827
Lythrum alatum Pursh; 5; P 26719

MALVACEAE

**Abutilon theophrasti* Medikus; 5; P 26802
Hibiscus laevis All.; 4; P 26755
Hibiscus lasiocarpos Cav.; 4; P 26826
**Sida spinosa* L.; 5; P 26790

MENISPERMACEAE

Menispermum canadense L.; 1; P 26421

MOLLUGINACEAE

**Mollugo verticillatus* L.; 5; P 26876

MORACEAE

**Maclura pomifera* (Raf.) Schneider; 1; P 26315
**Morus alba* L.; 5; P 26342
Morus rubra L.; 1; P 26319

NYSSACEAE

Nyssa sylvatica Marshall; 1; P 26319

OLEACEAE

Fraxinus pennsylvanica Marshall; 1, 2, 4; P 26378

ONAGRACEAE

Ludwigia alternifolia L.; 4; P 26749
Ludwigia palustris (L.) Ell.; 4; P 26850
Ludwigia polycarpa Short & Peter; 4; P 26726
Oenothera biennis L.; 5; P 26817
Oenothera laciniata Hill; 5; P 26447
Oenothera pilosella Raf.; 5; P 26435

OXALIDACEAE

Oxalis dillenii Jacquin; 5; P 26333

PHYTOLACCACEAE

Phytolacca americana L.; 1; P 26397

PLANTAGINACEAE

**Plantago lanceolata* L.; 5; P 26328
Plantago rugelii Dcne.; 5; P 26734
Plantago virginica L.; 5; P 26162

POLEMONIACEAE

Phlox divaricata L.; 1; P 26194

POLYGONACEAE

Polygonum amphibium L.; 3, 4, 5; P 26727
**Polygonum aviculare* L.; 5; P 26808
Polygonum buxiforme Small; 5; P 26807
**Polygonum caespitosum* Blume; 1, 4; P 26844
Polygonum hydropiperoides Michx.; 3, 4; P 26748
Polygonum pensylvanicum L.; 2, 4, 5; P 26796
Polygonum punctatum Ell.; 1, 4, 5; P 26799
Polygonum ramosissimum Michx.; 1, 5; P 26791
Polygonum scandens L.; 2, 5; P 26881
Polygonum virginianum L.; 1; P 26849
**Rumex acetosella* L.; 5; P 26443
Rumex altissimus Wood; 4, 5; P 26163
**Rumex crispus* L.; 1, 5; P 26427
Rumex verticillatus L.; 1, 2, 3, 4; P 26401

PORTULACACEAE

Claytonia virginica L.; 1; P 26188

PRIMULACEAE

Lysimachia ciliata L.; 1, 2, 4, 5; P 26441
Samolus valerandii L.; 2, 4; P 26728

RANUNCULACEAE

Anemone canadensis L.; 5; P 26334
Clematis pitcheri Torrey & Gray; 1; P 26438
Myosurus minimus L.; 5; P 26167
Ranunculus hispidus Michx. var. *nitidus* (Ell.) T. Duncan; 1, 2; P 26198
Ranunculus micranthus Nutt.; 1, 2; P 26196

ROSACEAE

Agrimonia pubescens Wallroth; 1; P 26708
Crataegus crus-galli L.; 1, 2; P 26413
Crataegus mollis (Torrey & Gray) Scheele; 1, 2; P 26195
Fragaria virginiana Duchesne; 5; P 26152
Geum canadense Jacq.; 1, 2; P 26412
Geum vernum (Raf.) Torrey & Gray; 1; P 26150
Potentilla norvegica L.; 1, 5; P 26879
**Potentilla recta* L.; 5; P 26394

Potentilla simplex Michx.; 5; P 26337
Prunus hortulana Bailey; 1; P 26190
Prunus serotina Ehrh.; 5; P 26156
Rosa carolina L.; 5; P 26434
Rosa setigera Michx.; 3, 4; P 26433
Rubus flagellaris Willd.; 5; P 26149
Rubus pensylvanicus Poiret; 1, 5; P 26313

RUBIACEAE

Cephalanthus occidentalis L.; 1, 2, 3, 4; P 26747
Galium aparine L.; 1, 5; P 26296
Galium obtusum Bigelow; 1, 4; P 26416
**Galium pedemontanum* (Bellardi) Allioni; 5; P 26393
Spermacoce glabra Michx.; 1, 3; P 26770

SALICACEAE

Populus deltoides Marshall; 1, 2; P 26183
Populus heterophylla L.; 4; P 26377
Salix exigua Nutt.; 2, 4, 5; P 26148
Salix nigra Marshall; 2, 3, 4, 5; P 26184

SAURURACEAE

Saururus cernuus L.; 1, 2, 3, 4; P 26756

SAXIFRAGACEAE

Penthorum sedoides L.; 1, 3, 4; P 26809

SCROPHULARIACEAE

Agalinis tenuifolia (Vahl) Raf.; 5; P 26841
Chelone obliqua L.; 1, 4; P 26873
Gratiola neglecta Torrey; 5; P 26417A
Leucospora multifida (Michx.) Nutt.; 4, 5; P 26732
Lindernia dubia (L.) Pennell var. *anagallidea* (Michx.) Cooperrider; 5; P 26417B
Mimulus alatus Ait.; 1, 4; P 26773
Penstemon digitalis Nutt.; 1, 5; P 26420
Penstemon laevigatus Ait.; 5; P 26340
**Veronica arvensis* L.; 5; P 26172
Veronica peregrina L.; 5; P 26173

SOLANACEAE

**Datura stramonium* L.; 5; P 26803
Physalis heterophylla Nees; 5; P 26459
Physalis longifolia Nutt. var. *subglabrata* (MacKenzie & Bush) Cronquist; 1; P 26862
**Solanum carolinense* L.; 5; P 27622
Solanum ptycanthum Dunal; 5; P 26880

ULMACEAE

Celtis laevigata Willd.; 1; P 27031
Celtis occidentalis L.; 1; P 26882
Ulmus americana L.; 1; P 26147

URTICACEAE

Boehmeria cylindrica (L.) Swartz; 1, 2, 4; P 26759
Laportea canadensis (L.) Weddell; 1, 2; P 26845
Parietaria pensylvanica Muhl.; 1; P 26320
Pilea pumila (L.) Gray; 1, 2, 4; P 26812

VALERIANACEAE

Valerianella radiata (L.) Dufresne; 5; P 26336

VERBENACEAE

Phyla lanceolata Loureiro; 4, 5; P 26379
Verbena urticifolia L.; 5; P 26823

VIOLACEAE

Viola missouriense Greene; 1, 4, 5; P 26329
**Viola rafinesquii* Greene; 5; P 26170

VITACEAE

Ampelopsis cordata Michx.; 1, 2; P 26798
Vitis cinerea Engelm.; 1; P 26436

Table 1. Density, basal area, relative density, relative dominance, importance value, and average diameters of the tree species encountered at the Chauncey Marsh Natural Area, Lawrence County, Illinois.

Species	Common Name	Density (#/ha)	Basal Area (m2/ha)	Rel. Den.	Rel. Dom.	I.V.	Av. Diam (cm)
Carya laciniosa	Kingnut Hickory	97.6	4.93	27.7	17.2	44.9	20.3
Liquidambar styraciflua	Sweet Gum	30.8	5.45	8.7	19.2	27.9	45.0
Quercus palustris	Pin Oak	21.6	6.13	6.1	21.5	27.6	56.6
Acer saccharinum	Silver Maple	23.4	3.24	6.6	11.4	18.0	34.2
Ulmus americana	American Elm	44.2	0.87	12.5	3.1	15.6	13.5
Quercus bicolor	Swamp White Oak	21.6	1.70	6.1	6.0	12.1	24.0
Celtis occidentalis	Hackberry	29.8	0.68	8.4	2.4	10.8	13.8
Fraxinus pennsylvanica	Green Ash	17.4	1.37	4.9	4.8	9.7	26.2
Quercus macrocarpa	Bur Oak	16.4	1.21	4.7	4.3	9.0	22.6
Gleditsia triacanthos	Honey Locust	4.8	1.02	1.4	3.6	5.0	49.1
Cercis canadensis	Redbud	15.6	0.14	4.4	0.5	4.9	9.9
Carya illinoinensis	Pecan	9.0	0.41	2.6	1.4	4.0	18.7
Acer rubrum	Red Maple	4.8	0.54	1.4	1.9	3.3	27.1
others*		16.2	0.77	4.5	2.7	7.2	--
	Totals	353.2	28.46	100.0	100.0	200.0	

* The other species, by decreasing IV, include *Carya cordiformis* (Bitternut Hickory), *Populus deltoides* (Cottonwood), *Celtis laevigata* (Sugarberry), *Diospyros virginiana* (Persimmon), *Acer negundo* (Box Elder), *Crataegus mollis* (Red Haw), *Platanus occidentalis* (Sycamore), *Juglans nigra* (Black Walnut), *Ulmus rubra* (Slippery Elm), *Prunus hortulana* (Wild Goose Plum), and *Quercus shumardii* (Shumard's Oak).

Table 2. Density (#/ha) by diameter classes of the tree species encountered at the Chauncey Marsh Natural Area, Lawrence County, Illinois.

	Diameter Class (cm)								
Species	6-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Carya laciniosa	39.2	21.0	9.2	13.0	10.2	3.8	1.0	0.2	--
Liquidambar styraciflua	0.8	1.6	2.0	6.4	7.0	7.8	4.6	0.2	0.4
Quercus palustris	0.8	0.6	0.4	1.8	3.4	5.2	4.4	2.8	2.2
Acer saccharinum	3.4	7.0	1.6	2.2	3.0	1.2	2.8	1.0	1.2
Ulmus americana	20.0	17.8	3.4	2.0	0.8	0.2	--	--	--
Quercus bicolor	6.8	6.2	3.0	1.6	1.2	1.2	0.6	0.2	0.8
Celtis occidentalis	14.0	11.6	1.6	1.2	0.8	0.6	--	--	--
Fraxinus pennsylvanica	4.8	3.6	2.4	1.8	3.2	0.8	0.6	--	0.2
Quercus macrocarpa	5.2	5.4	2.0	0.6	1.2	0.6	0.4	0.4	0.6
Gleditsia triacanthos	0.2	--	0.6	0.4	1.2	1.4	0.4	0.4	0.2
Cercis canadensis	10.4	5.0	0.2	--	--	--	--	--	--
Carya illinoinensis	4.2	2.0	0.6	0.6	1.2	0.4	--	--	--
Acer rubrum	2.0	1.2	--	0.2	0.4	0.2	0.4	--	0.4
others	6.4	6.4	1.2	0.2	0.8	0.2	0.8	--	0.2
Totals	118.2	89.4	28.2	32.0	34.4	23.6	16.0	5.2	6.2

Table 3. Density (#/ha) of seedlings (<50 cm tall), small saplings (>50 cm tall and <2.5 cm dbh), and large saplings (2.5-5.9 cm dbh) at the Chauncey Marsh Natural Area, Lawrence County, Illinois.

Species	Seedlings	Small Saplings	Large Saplings
Carya laciniosa	1377.8	760.0	86.7
Quercus palustris	1066.7	--	1.3
Fraxinus pennsylvanica	666.7	386.7	14.7
Celtis occidentalis	488.9	26.7	33.3
Gleditsia triacanthos	133.3	--	--
Ulmus americana	88.9	66.7	42.7
Crataegus mollis	88.9	40.0	--
Carya illinoinensis	44.4	--	12.0
Cercis canadensis	--	13.3	12.0
Quercus macrocarpa	--	--	12.0
others (5 species)	88.9	26.7	6.6
Totals	4044.5	1320.1	221.3

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 53-58

received 5/15/98
accepted 8/13/98

Distribution and Ecology of *Corydalis curvisiliqua* Engelm. var. *grandibracteata* Fedde (Papaveraceae) in Illinois

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ABSTRACT

Corydalis curvisiliqua Engelm. var. *grandibracteata* Fedde (large-bracted corydalis), a species listed as threatened in Illinois, was first reported for the state in 1986. Presently this taxon is known from the major sand areas of western Illinois (Cass, Henderson, Morgan, and Scott Counties), and from adventive populations in four additional counties. Large populations, some exceeding 23,000 #/ha, were in fallow fields. In sand prairies, the large-bracted corydalis populations averaged a few hundred #/ha, being associated with small disturbance patches.

INTRODUCTION

Corydalis curvisiliqua Engelm. var. *grandibracteata* Fedde (large-bracted corydalis), is a yellow-flowered, winter annual native to northeast Texas, Oklahoma and Kansas (Ownbey 1947, Brooks 1986), with outliers in Iowa (Ownbey 1947) and central Illinois (Colin et al. 1987). First collected in Illinois by R. T. Rexroat in 1953 (ISM 42544 and ISM 51932), the collections were mis-identified as *Corydalis micranthus* (Engelm.) Gray. Recognized as *C. curvisiliqua* var. *grandibracteata* by Colin et al. (1987), this taxon is now considered to be a native component of the Illinois flora (Mohlenbrock 1986). It is presently listed as threatened in Illinois (Herkert 1991), mostly because it was recently recognized as a distinct taxon (Colin et al. 1987), and its limited distribution in the state.

The large-bracted corydalis is mostly restricted to the Illinois River and Mississippi River Sand Areas Natural Division (Schwegman 1973), occurring in Cass, Henderson, Morgan and Scott Counties (Tables 1 & 2). Also, adventive populations, which may persist for only a few years, have been found along roadsides and railroads in Brown, Mercer, Pike, and Sangamon Counties. This study was undertaken to determine the distribution of this taxon in Illinois, and to outline the conditions necessary for its continued survival.

MATERIALS AND METHODS

All known populations of the large-bracted corydalis were visited during the spring of 1996 and 1997, and selected sites were sampled using ten 100m2 circular plots located at 15 m intervals along a line transect. In each plot all large-bracted corydalis plants were counted, the amount of vegetation cover estimated, and the density (#/ha) of the large-bracted corydalis determined.

At each site 60 individual plants were randomly selected and the number of inflorescences and the number of flowers per inflorescence were recorded without disturbing the plants. Seed set was determined in mid-June when the fruits developed.

DESCRIPTION OF STUDY AREAS

Cass # 1: A 60 ha fallow field 4 kms south of Beardstown, Illinois (SE1/4 S3 T17N R12W). Watermelons were cultivated in the field the previous year (1995).

Cass # 2: A 20 ha pine plantation in a sand prairie 4 kms south of Beardstown, Illinois (SW1/4 S3 T17N R12W).

Cass # 3: A sand prairie about 100 ha in size just west of the Burlington Northern railroad, 2.5 kms south of Beardstown, Illinois (NE1/4 S35 T18N R12W).

Cass # 4: A disturbed sand prairie about 20 ha in size near an old landfill 0.5 kms south of the junction of the Burlington Northern Railroad and Stock Lane (SW1/4 S35 T17N R12W).

Henderson # 1: A fallow wheat field about 2.5 kms west of Bald Bluff, Illinois (NE1/4 S19 T12N R4W). More than 50 ha in size, the field had been fallow for several years.

Morgan # 1: A hog lot about 10 ha in size 2.5 kms south of Meredosia, Illinois (SE1/4 S27 T16N R13W). Hogs were present in this lot during the fall of 1995.

Scott # 1: A fallow field near Coon Run Creek 2.5 kms northeast of Naples, Illinois (SW1/4 Sec 5 T15N R13W). More than 50 ha in size, the field was fallow a few years before the study.

Scott # 2: A disturbed sand prairie about 8 ha in size, at the edge of an old dump 2.5 kms northeast of Naples, Illinois (NE1/4 Sec 5 T15N R13W).

RESULTS AND DISCUSSION

Seeds of the large-bracted corydalis germinate from October to early March, usually forming a branched rosette of bipinnatifid leaves. These stems elongate in early spring and develop a terminal, bracteate raceme with 1-20 (averaged 4-11 at the sites studied), two-lipped, long-spurred flowers exceeding 16 mm in length. As the inflorescence matures, axillary branches develop, each with a terminal inflorescence. Commonly 5-10 inflorescences develop from each plant, but sometimes as many as 45 (Table 1). The

fruits (capsules) mature about three weeks after anthesis, and produce 5-13 (averaged 7.1-9.3 at the sites studied) seeds with an oily appendage (elaiosome). Depending upon available moisture the plant dies between the middle of May and the end of June, disintegrating rapidly. The seeds do not germinate upon dispersal, an after-ripening period being required.

Ants were commonly associated with the large-bracted corydalis, and their hills were frequently located at the base of the plants. After seed set, piles of seeds lacking elaiosomes were found near the ant hills. The only ants observed carrying seeds of the large-bracted corydalis were individuals of *Pheidole bicarinata* Mayr. Myrmecochory is undoubtedly associated with this species, this phenomenon being reported for other species in the genus (Hanzawa et al. 1985, Nakanishi 1994).

Large-bracted corydalis occurs in two distinct habitats: sand prairies, fallow fields and other extensively disturbed sandy habitats (Table 1). In the least disturbed sand prairies (Cass # 3 and 4) individuals of the large-bracted corydalis were widely scattered, less than 200 #/ha. Cover usually exceeded 80%, the large-bracted corydalis individuals were restricted to small disturbance patches and open sand between clumped perennials. In a pine plantation (Cass # 2) and at the edge of an old dump (Scott # 2), where the sand prairies were disturbed, the number of large-bracted corydalis plants increased significantly, sometimes exceeding 13,000 #/ha. In recently fallowed fields and other extensively disturbed habitats of the sand areas (Cass # 1 and Henderson # 1), the corydalis plants were abundant, densities usually exceeding 22,000 #/ha (Table 1).

Large-bracted corydalis plants have also been observed in a few other disturbed habitats, particularly railroad ballast and gravelly and sandy roadsides. These populations tend to be transient and easily extirpated. One population in a hog lot (Morgan # 1) averaged 660 #/ha (Table 1). At this site, dominated by annual weeds, the vegetative cover averaged 75%. A list of all known large-bracted corydalis populations in Illinois are included in Table 2. Some of these populations extend across parts of three to six sections, others are small and isolated, covering only a few ha. These larger populations are not always contiguous, being interrupted by cultivated field and woodlots.

All of the large-bracted corydalis sites in Illinois occur on private land, none are in nature preserves or other state-owned sites. The data suggests that, at least in Illinois, disturbance is necessary for large populations to thrive. In the past, fire, blow-outs, and overgrazing, were probably important for this species' survival in sand prairies. Also, density and seed set can vary greatly due to rainfall patterns. Spring droughts severely decrease population sizes, and several years may be required before populations return to high levels, suggesting a poor seed bank.

This taxon has been cultivated since 1981 at Rivendell Botanic Garden, Schuyler County, Illinois. By maintaining an open habitat in sand, the large-bracted corydalis was easy to cultivate and made an excellent ornamental. Current agricultural practices will probably allow for the survival of this species in Illinois, but protected sand prairies with a moderate disturbance regime would be advisable.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to Mr. Marc DuBois of Washington, Illinois for the identification of the ant species, to Dr. Paul Shildneck of Mt. Zion, Illinois for his help in the recognition and verification of the large-bracted corydalis in the Illinois flora, and to William McClain of the Illinois Department of Natural Resources and Dr. Alfred Koelling of the Illinois State Museum for reviewing the manuscript.

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Table 1. Habitat, vegetative cover (%), density (#/ha), floral and fruit characteristics at the *Corydalis curvisiliqua* var. *grandibracteata* sites.

Study site	Habitat	Density (#/ha)	Cover (%)	Infl./ Plant	Flowers/ Infl.	Seeds/ Fruit
Henderson #1	fallow field	23,760	60	6.8	11.0	7.8
Cass #1	fallow field	22,540	60	9.9	7.9	9.1
Cass #2	sand prairie (disturbed)	13,440	70	6.3	8.3	5.8
Scott #1	fallow field	4,090	75	5.6	6.0	9.3
Scott #2	sand prairie (disturbed)	1,310	70	5.1	3.9	7.1
Morgan #1	hog lot	660	75	10.2	8.6	8.8
Cass #3	sand prairie	170	80	7.1	4.4	7.2
Cass #4	sand prairie	140	80	5.0	5.4	8.1

Table 2. Known Illinois populations of *Corydalis curvisiliqua* var. *grandibracteata* as of 1998.

County and map coordinants	general location	size (ha)	First Seen
Brown Co.			
SW1/4 S35 T2S R2W	5 kms SE of Versailles	2	1983*
Cass Co.			
S23, S26, S35 T18N R12W and S1, S2, T17N R12W	railroad SE of Beardstown	580	1983
S3, S9, S10 T17N R12W	6.5 kms S of Beardstown	660	1984
Henderson Co.			
NE1/4 S19 T12N R4W	2.5 kms W of Bald Bluff	75	1955
Mercer Co.			
exact locality not found	N of New Boston	--	1955*
Morgan Co.			
S27, S33, S34 T16N R13W	2.5 kms S of Meridosia	660	1983
Pike Co.			
NW1/4 Sec 1 T35N R2W	1 km NW of Meridosia	2	1984
Sangamon Co.			
SW1/4 S19 T15N R6W	2.5 kms SW of Curran	2	1988
Scott Co.			
S4, S5, S6 T15N R13W	2.5 kms NE of Naples	600	1984
S19 T15N R13W and S13, S24 T15N R14W	2.5 kms S of Naples	600	1984

* probably extirpated

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 59-67

received 1/15/98
accepted 8/22/98

Embryo Germination in *Acer ginnala* Maxim. and the Activity of an Endogenous Exudate

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ABSTRACT

The Amur maple (*Acer ginnala* Maxim.), a small, pollution and stress-tolerant ornamental tree, is commonly planted in the northern United States. In preliminary germination studies, a reddish-brown exudate was produced from the testa surrounding the embryo. Embryos with testae in place did not germinate, whereas embryos with the testae removed, or even slightly damaged, germinated in approximately 9 days. Removal of the testa and subsequent embryo culture in total darkness permitted embryo germination, indicating that the testa may control germination by chemical means rather than as a physical barrier to light. Periodic removal of the exudate followed by subsequent analysis of newly produced exudate indicated a decrease in concentration over time, suggesting that gradual disintegration or inactivation of the testa may be a timing mechanism for germination. The exudate inhibited the development of lateral roots in lettuce seedlings, suggesting that it may posses allelochemical properties as well. Our results suggest that the testa of *Acer ginnala* provides a timing mechanism for its own embryo germination and may also influence the adjacent microenvironment through the secretion of this exudate.

Key words: Amur maple, phytochemicals, sterilization, germination, mercuric chloride, testa, exudate.

INTRODUCTION

The Amur maple (*Acer ginnala* Maxim.) is a small, pollution and stress-tolerant ornamental tree. It is native to Siberia and is planted in the northern United States (Ebinger and McClain, 1991; Norton, 1987). Amur maple fruits require a stratification time of up to 150 days (U.S. Forest Service, 1948), but investigators have demonstrated that removal or disruption of the testa, the cell layer covering the zygotic embryo in mature maple fruits (sensu Dumbroff and Webb, 1970), resulted in much faster germination (7-15 days). The presence of a testa surrounding the zygotic embryo raised questions regarding

its role in regulating the timing of germination, as no germination was observed in vitro in embryos with intact testae. The testa could inhibit germination by preventing light and water from reaching the embryo. However, Dumbroff and Webb (1970) determined that *A. ginnala* fruits were light sensitive and that germination occurred at a higher rate in fruits germinated in the dark versus those germinated in continuous light. This raises the possibility of the testa functioning as a physical barrier to light.

Alternatively the testa may produce inhibitors which act as a chemical barrier for germination. As such, the gradual degeneration of the testa following prolonged exposure to external factors could act as a timing mechanism for germination. The chemical compositions of fruits of several *Acer* species change during stratification (Pinfield and Davies, 1978; Webb et al., 1973), and the testa may contribute to these changes. Investigators have also detected chemicals which inhibit the growth of other plants in the fruits of several maples. For example, water extracts of sycamore maple, *Acer pseudoplatanus* L., strongly inhibit the growth of yellow birch, *Betula alleghaniensis* Britt. (Fisher, 1987), while similar extracts from the roots of nine other species of *Acer* were also found to be to be inhibitory (Podtelok, 1972; Maclaren, 1983).

The purpose of this study was to investigate: (1) an effective technique for surface sterilization and germination of Amur maple fruits, (2) the inhibitory role of the testa in Amur maple germination, (3) the role of Amur maple exudate in influencing the development of seedlings of other plants, and (4) preliminary physical characteristics of the exudate.

METHODS

Materials: All chemicals were purchased from Sigma Chemicals, Inc. (St. Louis, MO, USA), unless otherwise specified. *Acer ginnala* fruits were purchased from the F.W. Shumacher Co., or were collected from established open-pollinated plantings on the campus of Southern Illinois University at Edwardsville, and were stored in plastic bags at 4C. Black-Seeded Simpson Lettuce (*Lactuca sativa* L.) seeds were purchased from a local vendor. Lettuce seeds were chosen for their rapid germination rates and because they had been used previously in bioassays to determine the activity of plant extracts (Li et al., 1992).

Surface sterilization and germination of Amur maple fruits: For surface sterilization, a 20 minute 1% mercuric chloride treatment (PhytaSource, 1994) was applied to winged fruits, which were then rinsed twice in sterile distilled water. At this point, wings and pericarps were removed, leaving testa-covered embryos, which were the subjects of this study. The testa-covered embryos were then transferred to a solid medium containing Phytagar (6.5 g/L; Life Technologies, Gaithersburg, MD) in water with no nutrients, and were incubated at 25C. Only data from uncontaminated samples were included in our results.

Surface sterilized *A. ginnala* fruits were subjected to one of four treatments then examined for germination. (1) Testa-covered embryos were incubated under cool white fluorescent light (60 $\mu E\ m^{-2}\ s^{-1}$) with a 16h photoperiod. (2 and 3) The testae were gently scraped from embryos in the light using a sterile scalpel, and these embryos were either (2) exposed to light as above or (3) kept completely in the dark under aluminum foil. (4)

The testae were removed from the embryos under complete darkness (0 μE m^{-2} s^{-1}) by gently scraping the embryos while enclosed in a cardboard box (with holes for access) which was sealed with several layers of black plastic and taped to the surface of a horizontal laminar flow hood. Scraped embryos were placed on a solid medium, then the petri dishes were wrapped with aluminum foil, all under complete darkness. A Li-Cor LI-189 light meter (Li-Cor, Inc., Lincoln, NE) was used to measure light levels. Each experiment was performed twice using 20-30 embryos per treatment.

Inhibition of test plantlet root development by Amur maple exudate: Testa-covered *A. ginnala* embryos were placed in petri dishes containing Phytagar (6.5 g/L). The embryos were removed from the medium after seven days. Fifteen lettuce seeds or seedlings were used for each of the four treatments, and seeds were surface sterilized using a 0.25% solution of commercial sodium hypochlorite for 10 minutes, followed by two rinses with sterile deionized water. A lettuce seed or plantlet was then placed in the center of the circle of exudate which remained in the medium following removal of the testa-covered embryo. Day 0 seeds were removed from their commercial packaging and placed in the exudate circle. Day 1 seeds were cultured on medium containing 6.5 g/liter Phytagar for one day before being exposed to the exudate. Day 2 seeds were cultured for two days prior to exposure, etc. Control seeds and plantlets were lifted and replaced on the medium to simulate the physical handling which the other seeds or plantlets experienced. Lateral roots were counted after one week in culture. For our purpose, any root other than the primary root was considered to be a lateral root. Root count data were analyzed using Kruskal-Wallis nonparametric ANOVA followed by a nonparametric analogue to the Student-Newman-Keuls multiple range test (Zar, 1996). A $\underline{P} \leq 0.05\%$ experiment-wise error rate was used. The Systat (R) statistical package was used for the Kruskal-Wallis test and for computing rank sums (Wilkinson, 1989).

Physical analysis of Amur maple exudate: To harvest the exudate, five testa-covered embryos were placed in a modified double microcentrifuge tube apparatus. A one mm hole was made in the bottom of a 0.75 ml microcentrifuge tube and its lid was removed. This tube was placed inside a 1.5 ml microcentrifuge tube. Embryos in modified tubes were centrifuged using a microcentrifuge for 20 seconds at 10,000 x g, 10 seconds at 14,000 x g, and 30 seconds at 10,000 x g. Two approaches were taken to spectrophotometrically analyze the exudate. One method involved six plates of embryos (5 per plate). The testa-covered embryos were centrifuged after being incubated for 2, 4, 6, 8, 10, or 13 days. The exudate collected each day was diluted 1:100 with distilled water and analyzed spectrophotometrically to measure absorbance changes at wavelengths of 260nm, 280nm, 380nm, 480nm, 580nm, and 680nm. The second method involved centrifuging embryos from each plate, returning them to their plates of origin, then spinning these same embryos again on days 2, 4, 6, 8, 10 and 13. Exudates were diluted 1:100 with distilled water and analyzed as above.

RESULTS AND DISCUSSION

Surface sterilization of Amur maple fruits: A 1% mercuric chloride treatment of fruits followed by two rinses with sterile water was effective in reducing contamination (from virtually 100% contamination of untreated control fruits to < 10% contamination).

Treatment with mercuric chloride did not affect fruit viability, germination, or exudate production (data not shown).

Observation of exudate production: Testa-covered embryos of *A. ginnala* were incubated on a solid medium. A dark reddish-brown exudate was observed on the upper surface of the testa in "pools" as well as in a dark "halo" which diffused into the medium under the embryo. Because the upper surface was not in contact with the medium, the presence of the exudate on this surface indicates that the exudate is not simply being washed off the surface of the embryo.

Effect of testa removal on embryo germination: Two experiments were conducted to analyze the effect of light on embryo germination following removal of the testa. The combined data from these experiments are presented here, as the acquisition of useful data under these conditions without introducing contaminating microorganisms was very difficult. When the pericarp and testa were removed from embryos, followed by incubation in the light, embryos germinated in seven to nine days (94% in uncontaminated experiments). A second set of embryos, from which the pericarp and testa had been removed in the light, were transferred to the dark. These germinated in 10-11 days at a slightly lower rate (67% in uncontaminated experiments) than embryos which germinated in the light. Despite an initial etiolated appearance, these seedlings grew and thrived. A third set of embryos from which the pericarp and testa had been removed in the dark were incubated under conditions of complete darkness and were also able to germinate (71% in uncontaminated experiments), but required subsequent light treatment for plantlet development. Embryos covered with intact testae did not germinate (0%) in light or darkness within a 120 day period, although slight physical nicking of the testa layer resulted in rapid germination. Dumbroff and Webb (1970) suggest that the role of the testa may be in restricting the rate of water uptake. While our observations do not contradict these results, we have observed that *A. ginnala* embryos germinating in vitro do not remain in physical contact with the exudate "halo" in the medium. This suggests that perhaps the exudate is affecting germination through chemical inhibition. We plan to examine the interaction between germinating *A. ginnala* embryos and the exudate.

Inhibition of lettuce root development by Amur maple exudate: The timing of exposure of germinating lettuce seeds and seedlings to the exudate significantly affected the mean number of lateral roots developed after one week of germination. Lettuce seeds exposed to the exudate on Day 0 [$\bar{x} = 0.57 \pm 0.20$], Day 1 [$\bar{x} = 0.00 \pm 0.00$], or Day 2 [$\bar{x} = 0.73 \pm 0.36$] had significantly fewer lateral roots (Figure 1) as compared to an untreated control [$\bar{x} = 1.61 \pm 0.31$]. The most severe lateral root inhibition occurred in seeds exposed to the exudate one day after being plated (beginning the germination process). Treated seedlings showed both a marked decrease in the number of lateral roots per plant and a noticeable reduction in root hairs (Figure 2; photograph of Control vs. Day 1 Lettuce). The longer the plantlets were allowed to develop (beyond Day 1) before exposure to the exudate, the less affected they were by the exposure (data not shown). These data suggest that the test seeds are vulnerable to the effects of the exudate, but that soon after the seeds germinate, the seedlings are no longer significantly affected. Other investigators made a comparable observation that "(chemical) control (of competitors) is restricted to germination and establishment. Once the plants are established, they generally survive" (Pickett and Baskin, 1973).

Physical analysis of Amur maple exudate: Spectrophotometric analyses of exudates provided significant peaks only at 260 and 280 nm. Analyses of exudates collected only once from testa-covered embryos on a solid medium after various lengths of time revealed that the absorbance of the exudate did not substantially change over time (data not shown). However, when exudate from a set of testa-covered embryos was collected every 2-3 days for 13 days, exudate absorbance decreased over time at 260 and 280 nm (Figure 3). This decrease in concentration may be due to exudate production decreasing over time, exudate being hydrolyzed or photolyzed over time, or exudate being diluted with water taken up from the medium. One of these hypotheses, that absorption of water from the medium leads to a dilution of the exudate, is analogous to the effect of moisture uptake from the soil on the concentration of the exudate in nature.

This study provides additional information (1) on germination physiology in *Acer ginnala* through the assessment of the role of the testa, (2) by documenting a reduction of lateral root formation in lettuce following exposure to the exudate, and (3) by initiating a spectrophotometric analysis of the exudate. We conclude that the testa plays a role in inhibiting the germination of Amur maple as more than just a physical barrier to light. Also, the exudate may function in inhibiting early seedlings of competitive companion species in the wild.

ACKNOWLEDGEMENTS

The authors would like to thank Susan Allen, Henry Chen, Shannon Dickson, and Carrie Kusturin for their contributions to this project. We also thank Dr. George Yatskievych, Missouri Botanical Garden, for identification of our original fruits; Ms. Janette Koenig for Russian- English translation of a background article. Thanks also to the Illinois State Academy of Sciences (P.B.V.) and the SIUE Program in Environmental Studies, whose funding made this project possible.

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Figure 1. Mean number and standard error of lateral roots in lettuce seedlings at specific times during their development. Day 0 samples were exposed as seeds, Day 1, one day after beginning germination in culture, and so on. Asterisks are used to distinguish among groups which differ from the control at the $\underline{P} \leq 0.05$ experiment-wise. Control seeds were not exposed to the exudate.

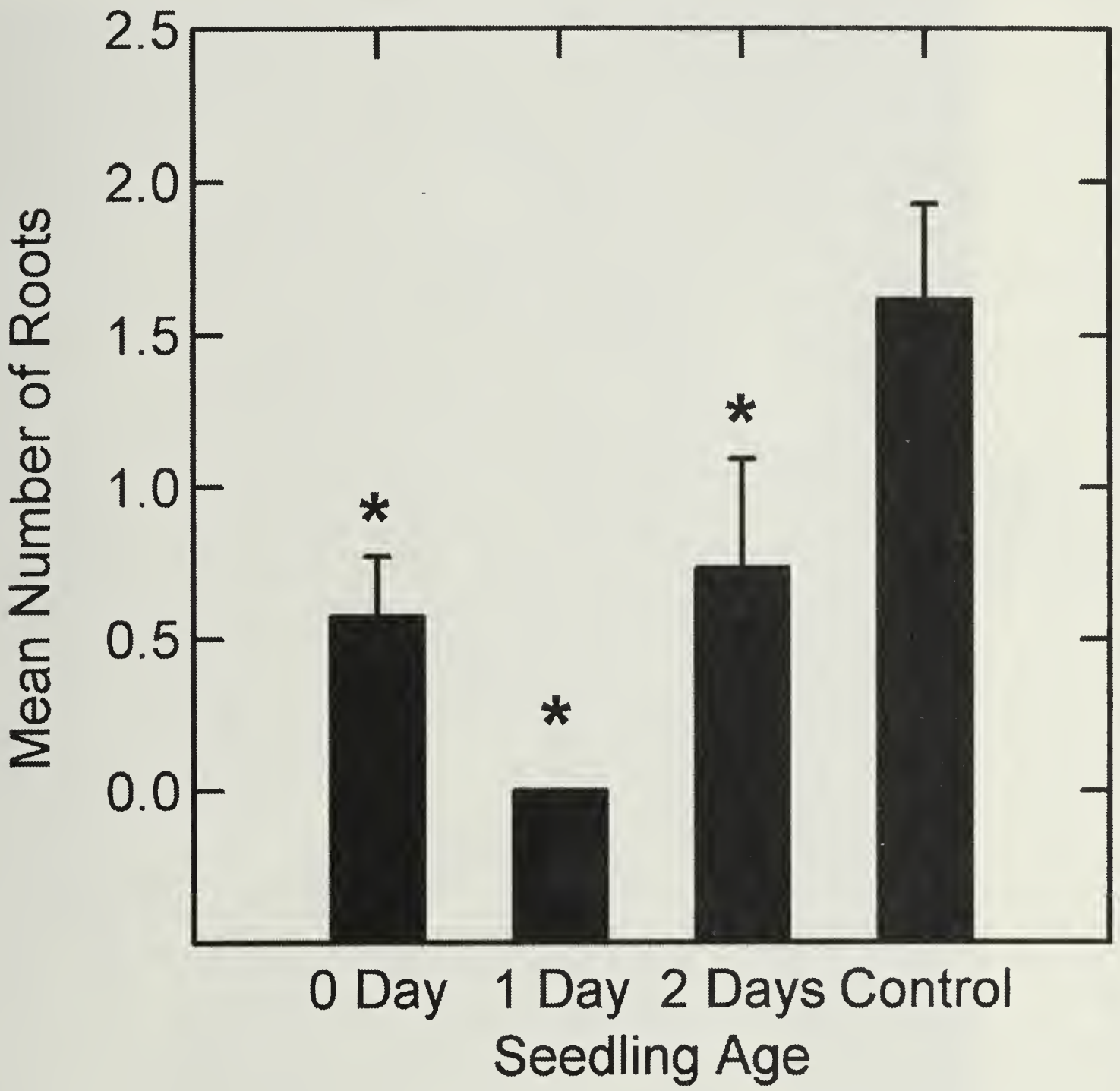
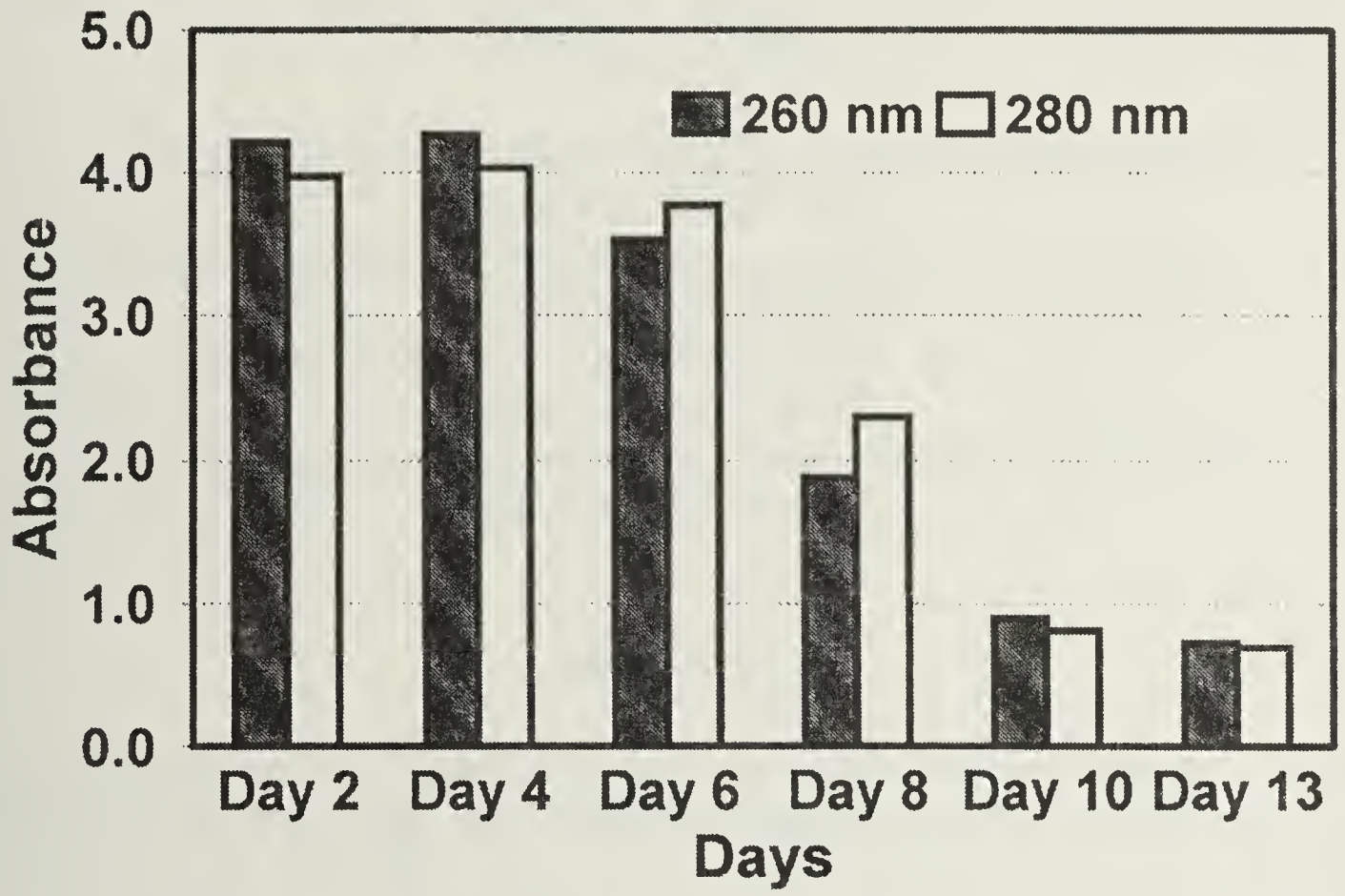


Figure 2. Photograph of lettuce control (left) versus Day 1 lettuce treated with *A. ginnala* exudate (right), taken four days after the initiation of the experiment. Note also the difference in the size of the seedlings (plate diameter 95 mm for reference).

Figure 3. Optical density of testa exudate. Seeds were centrifuged following two days of being cultured on solid medium. The same seeds were then returned to culture and centrifuged again after 4, 6, 8, 10, and 13 days.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 69-78

received 7/16/98
accepted 10/1498

Reintroduction and Status of the River Otter (*Lutra canadensis*) in Illinois

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ABSTRACT

Although river otters (*Lutra canadensis*) were common in Illinois during early European settlement, habitat degradation and unregulated harvests caused populations to decline dramatically by the mid-1800s. Otters were considered rare in the state by the early 1900s, and were listed as a state endangered species in 1989. Recovery strategies developed by the Illinois Department of Natural Resources included reintroducing otters in suitable but unoccupied habitats. Wild otters obtained from Louisiana were released in the Wabash (n = 137), Kaskaskia (n = 72) and Illinois (n = 137) River basins from January 1994 through March 1997. Dead otters recovered from 1994 through 1997 included more males (*n* = 20) than females (n = 9). Losses were attributed to hoop nets (n = 8), vehicles (n = 7), traps (n = 7), stress (n = 6), and domestic dogs (n = 1). Surveys and sightings indicated that otters were persisting and reproducing in release areas. Reports from outside of release areas suggested that native populations along the Mississippi and Cache Rivers were increasing and expanding their ranges. Otters had colonized the Central Mississippi Landscape Management Unit, probably as the result of releases in Missouri during the 1980s. Criteria for changing this species' status from endangered to threatened have been met.

INTRODUCTION

River otters (*Lutra canadensis*) were common and distributed widely in Illinois during early European settlement (Cory 1912, Mohr 1943). Habitat loss and unregulated harvests caused their numbers to decline by the early to mid-1800s (Hoffmeister and Mohr 1957, Thomas 1861), and they were rare or absent in most of northern and central Illinois by the early 1900s (Wood 1910, Cory 1912, Forbes 1912). Although protected from hunting and trapping by continuous closed seasons beginning in 1929 (Mohr 1943),

sightings became uncommon in the state by the mid-1900s (Brown and Yeager 1943, Hoffmeister and Mohr 1957).

A small population existed along the Mississippi River and its tributaries in northwestern Illinois during the 1980s (Thom 1981, Anderson 1982, Anderson and Woolf 1987). Reports from southern Illinois were clustered along the Cache River and suggested the existence of a second population (Anderson 1982). Anderson (1982) estimated that fewer than 100 otters existed in Illinois at that time. Listed as state threatened in 1977, the river otter's status was revised to state endangered in 1989 because its limited distribution and apparent scarcity suggested the population was at risk of extirpation.

A Recovery Team consisting of staff from the Illinois Department of Natural Resources (IDNR) and Illinois Endangered Species Protection Board (IESPB) was organized in 1993. The team recommended goals of re-establishing river otters in suitable habitats, monitoring populations, and conserving key habitats (Bluett et al. 1995). Tasks specified by the team included releasing river otters in the Wabash (n = 110), Kaskaskia (n = 60-70) and Illinois (n = 100-125) Landscape Management Units (LMUs, Fig. 1) (Bluett et al. 1995). We describe the reintroduction phase and status of recovery efforts through 1997.

METHODS

Otters of the same subspecies as occurs in Illinois (*L. c. lataxina*, van Zyll de Jong 1972) were purchased from a supplier in Louisiana (L.R. Sevin, Theriot, LA) who trained local fur trappers to capture wild otters in small leghold traps, then restrain, cage, and transport them to his facility using techniques that minimized injuries. There the otters were examined by a veterinarian, treated for any injuries, vaccinated for canine and feline distemper, and held in captivity in individual cages for 3-15 weeks. They were fed twice daily and provided water ad libitum.

The supplier combined two to three animals of the same sex in each cage two to three days before they were scheduled for transport. Otters were transported by vehicle from Louisiana to the University of Illinois' Dixon Springs Agricultural Experiment Station during a one to two day trip. A device designed by McCullough et al. (1986) was used to separate and restrain otters so that they could be tranquilized, examined, administered an antibiotic, vaccinated, treated for injuries, and marked with metal tags. The protocol for processing otters was developed by staff from the University of Illinois' College of Veterinary Medicine and approved by the University's Laboratory Animal Care Advisory Committee (Bluett 1995). Most otters were released at or near locations specified by the Recovery Plan (Bluett et al. 1995) within 48 hrs of their arrival in Illinois.

Posters displayed at IDNR offices and report forms printed in IDNR's Digest of Hunting and Trapping Regulations were used to solicit sighting information from the public during 1994 through 1997. Other common sources of reports included IDNR staff and researchers from the Cooperative Wildlife Research Laboratory at Southern Illinois University at Carbondale (Schieler 1995, Farrand 1997). Reports from the public were screened by a follow-up phone call or letter to evaluate their legitimacy and to collect additional information about exact locations of sightings. Sightings deemed reliable were added to IDNR's Natural Heritage Database.

Surveys of licensed fur trappers conducted by IDNR (Anderson et al. 1995, 1996a, 1996b; Anderson and Campbell 1998) included the question, "Have you seen a river otter or observed river otter sign in Illinois during the past three years?" Those responding affirmatively were asked to identify the sighting location(s) by county. We summarized annual results for trapping seasons that occurred during 1993-94 through 1996-97.

RESULTS

IDNR acquired 349 river otters and released 346 from January 1994 through March 1997 (Table 1). Two otters died shortly after they were tranquilized, and one was euthanized because of an injury sustained during restraint. Three otters judged to be in poor health were transported to Brookfield Zoo (Brookfield, IL), rehabilitated, and released near scheduled sites at a later date.

IDNR recovered the carcasses of 29 of the released otters as of 31 December 1997. Known sources of mortality included hoop nets (n = 7), vehicles (n = 7), traps (n = 7) and domestic dogs (n = 1). Six deaths were attributed to stress from transport and handling because the otters were recovered shortly after, and in the immediate vicinity of, release(s) without any signs of physical trauma. Cause of death was unknown for one otter, but lack of injuries and water detected in its lungs during necropsy suggested drowning in a hoop net. Losses were greater in the Wabash (n = 15) than the Illinois (n = 11) or Kaskaskia (n = 3) LMUs, and included more males (n = 20) than females (n = 9).

Recovery of kits from Lake Shelbyville (Kaskaskia LMU), the LaMoine River near Macomb (Illinois LMU), and two locations on the upper Illinois River verified births in release areas. Two kits recovered from Lake Shelbyville were probably from a single litter, as were six found on the LaMoine River. Two kits recovered near Henry, IL and one near Putnam, IL might have been from a single litter because they were about the same size, found three days apart and old enough to have traveled the eight km between locations. Three reports of family groups in the Wabash LMU (North Fork of the Embarras River, Skillet Fork and the Little Wabash River) and one from the Illinois LMU (Sangamon River) provided additional evidence of reproduction, as did the accidental capture of an untagged otter on the Little Wabash River in White County.

IDNR's Natural Heritage Database contained 356 reports of sightings from 1994 through 1997 (Table 2). Three of these occurred before the first release on 22 January 1994. Almost half of the sightings (42%) came from LMUs where releases occurred, including 54 from the Wabash, 38 from the Kaskaskia and 56 from the Illinois. More reports were received from the Wabash, Kaskaskia and Illinois LMUs during 1996 (n = 54) than in 1995 (n = 36) or 1994 (n = 25). Thirty-three sightings occurred in these areas during 1997.

Numbers of counties in which trappers reported seeing river otters or their sign during the past three years increased from 23 in 1993-94 to 36 in 1996-97, and numbers of trappers who reported observations increased from 40 to 70. Observations were reported from 56 different counties located in all seven LMUs during the four years of the survey. Thirty-eight counties had repeated observations (i.e., reports from two or more years). LMUs

with observations during at least three of the four years included the Rock/Mississippi North, Central Mississippi, Wabash, and Shawnee. Sightings from the Natural Heritage Database were more widespread (84 of 102 counties in the state) than those from the trapper survey, but both showed similar geographic patterns. For example, 51 counties had observations from both sources.

DISCUSSION

The number of otters released during recovery efforts exceeded the Recovery Team's recommendation of 270-305 (Bluett et al. 1995). Fifty otters released in the Patoka River System during 1997 by the Indiana Department of Natural Resources (S. Johnson, Indiana Dep. Nat. Resour., pers. comm.) will likely aid recovery efforts in the Wabash River Basin. Recent (1994-1997) reports verify the persistence of otters in LMUs where releases were made, and outnumber those from the previous decade by more than tenfold. Reports from other parts of the state substantiate observations by Anderson (1995) that (1) otters in northwestern Illinois appeared to be increasing and had expanded their range to include portions of the Rock River System, (2) the Cache River population appeared stable to increasing and had expanded its range to include portions of the Big Muddy River System, and (3) otters had colonized the Middle Mississippi River Tributaries, probably as the result of releases in Missouri during the 1980s.

Sources of mortality were similar to those reported for Missouri (Erickson and McCullough 1987). None of the deaths documented in Indiana were caused by hoop nets (Johnson et al. 1996), but releases occurred in areas where these devices were prohibited. Mortality rates cannot be estimated from data available for Illinois. We assumed first-year mortality rates were similar to those confirmed by radiotelemetry studies in Missouri (19%; Erickson and McCullough 1987) and Indiana (29%; S. Johnson, Indiana Dep. Nat. Resour., pers. comm.) because all three states obtained otters from the same source, used similar methods to process otters, and employed similar release strategies.

Given the reproductive biology of otters (Liers 1951, Wright, 1963), we expected that protocols for capturing and holding them would disrupt normal reproduction for about two years. Seven females had well-developed fetuses when released in the Little Wabash River System and were an exception. All others due to give birth the same year as their release had whelped in captivity and likely completed their estrus cycle unbred because they were held separately from males. These otters wouldn't breed until the spring following their release and would bear young approximately one year later. We attributed litters observed the year after releases (e.g., Skillet Fork and the North Fork of the Embarras) to two-year-old females which had reached sexual maturity, bred before their capture and given birth the next spring. Kits found on the LaMoine and Upper Illinois Rivers in 1997 could not have come from otters released in these areas earlier in the year. We suspect that these kits belonged to females which had dispersed there from the Central Mississippi LMU or from releases on the Spoon and Mackinaw Rivers in 1996.

No simple methods exist for censusing river otters (Melquist and Hornocker 1979), so most investigators (Zackheim 1982, Melquist and Dronkert 1987, Woolf et al. 1997) recommend a combination of indices to monitor population status (e.g., carcass collections, sighting reports, sign surveys, population models, surveys of trappers or agency biolo-

gists). Methods used in Illinois (i.e., sighting reports, trapper surveys) are adequate for immediate management needs (Woolf et al. 1997) and are consistent with the Recovery Team's minimum standards for assessing population status (Bluett et al. 1995). However, receipt of sighting reports can vary with the type and amount of effort to collect them as well as changes in public sentiment (e.g., reporting rates might decline as otters become more abundant and less of a novelty) (Woolf et al. 1997). We believe that one or more of these factors caused a decline in the number of reports received in 1997, and recommend implementation of a more standardized population index using guidelines provided by Woolf et al. (1997).

The Recovery Team established an objective of reclassifying river otters from endangered to threatened when "stable or increasing populations of reproducing individuals have been documented in at least 3 landscape management units." (Bluett et al. 1995:35). Given evidence of long-term (> 10 yrs) populations and range expansion in the Shawnee, Rock/Mississippi North and Central Mississippi LMUs, we concur with the IESPB's recent (21 Aug 1998) decision to change the river otter's status from endangered to threatened. The Recovery Team recommended delisting river otters from threatened status upon evidence of stable or increasing populations of reproducing individuals in five LMUs or in four LMUs if, in addition, their presence was documented in at least 60% of population management units therein (Bluett et al. 1995). While river otters were present and reproducing in six of seven LMUs, criteria recommended for delisting from threatened status were not met fully because we could not verify population trends (i.e., stable or increasing) with short-term (< 3 yrs) datasets available for release areas. Therefore, we recommend that the otter's status be reviewed every five years to determine if a change is warranted by data available at the time.

ACKNOWLEDGMENTS

We thank J. E. Buhnerkempe and A. Woolf for reviewing a draft of the manuscript. Staff and students from the University of Illinois' College of Veterinary Medicine played a key role in ensuring the health and welfare of river otters processed for release. Staff from the Division of Wildlife Resources, IDNR and members of the Illinois Chapter of the National Wild Turkey Federation captured wild turkeys for an interstate trade that accounted for 150 otters released in Illinois. We thank those who contributed toward the purchase of otters, including residents who made donations to the Wildlife Preservation Fund, hunters and trappers who supported the Illinois State Furbearer Fund through their purchases of Habitat Stamps, people who targeted their donations through the Illinois Conservation Foundation, the Martin Foundation, and the Division of Wildlife Resources, IDNR. Recovery efforts were funded in part by Federal Aid in Wildlife Restoration Project W-99-R, IDNR and the U.S. Fish & Wildlife Service cooperating.

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Table 1. River otter releases in Illinois, 1994-97.

LMU[a]	Body of water	County	Township, range	Month/year	No. otters released
Wabash	Little Wabash River	Jasper	T5N, R8E	1/94	25 (15 M, 10 F)
Wabash	Little Wabash River	Wayne	T1S, R9E	1/94	25 (15 M, 10 F)
Wabash	Embarras River	Coles	T11N, R9E	3/95	18 (10 M, 8 F)
Wabash	North Fork Embarras River	Clark	T9N, R14W	4/95	19 (9 M, 10 F)
Wabash	Skillet Fork	Wayne	T1N, R5E	3/95	20 (10 M, 10 F)
Wabash	Vermilion River	Vermilion	T20N, R12W	4/96; 3/97	30 (18 M, 12 F)
Wabash	Combined				137 (77 M, 60 F)
Kaskaskia	Lake Shelbyville	Moultrie	T13N, R5E	3/95; 4/95	24 (12 M, 12 F)
Kaskaskia	Carlyle Lake	Bond	T4N, R2W	2/96	25 (15 M, 10 F)
Kaskaskia	Shoal Creek	Montgomery	T8N, R4W	2/96	23 (14 M, 9 F)
Kaskaskia	Combined				72 (41 M, 31 F)
Illinois	Spoon River	Fulton	T8N, R2E	4/96	24 (12 M, 12 F)
Illinois	Mackinaw River	McLean[b]	T25N, R2E	4/96	28 (13 M, 15 F)
Illinois	LaMoine River	Schuyler	T3N, R3W	3/97	24 (15 M, 9 F)
Illinois	Illinois River	Mason[c]	T19N, R11W	3/97	26 (14 M, 12 F)
Illinois	Illinois River	Bureau	T16N, R10E	3/97	25 (14 M, 11 F)
Illinois	Quiver Creek	Mason	T22N, R7W	3/97	10 (6 M, 4 F)
Illinois	Combined				137 (74 M, 63 F)
Statewide	Combined				346 (192 M, 154 F)

[a] Landscape Management Units (LMUs) follow the Illinois Environmental Protection Agency's classification of major river basins (Illinois Environmental Protection Agency, 1996), with some modifications (e.g., grouping of smaller river basins to form a single unit).

[b] Includes secondary release sites on the Mackinaw River in McLean County (4 M, 3 F; T25N, R3E), Tazewell County (3 M, 1 F; T24N, R2W) and Woodford County (4 M; T25N, R1E).

[c] Includes a secondary release site on the Sangamon River in Menard County (2 M; T18N, R7W).

Table 2. Distribution of river otter reports for population management units and corresponding portions of the Mississippi, Ohio, and Wabash Rivers which adjoin Illinois, 1900 through 1997[a].

Landscape management unit	Population management unit[b]	Years of Reports 1900-50	1951-82	1983-93	1994-97[c]	Total
Rock/Mississippi North	Galena, Apple, and Plum River Systems	--	44	60	46	150
Rock/Mississippi North	Rock River System	--	18	28	74	120
Central Mississippi	Middle Mississippi River Tributaries	--	6	17	28	51
Fox/Des Plaines/Kankakee	Des Plaines River and Lake Michigan Tributaries	--	2	1	5	8
Fox/Des Plaines/Kankakee	Fox River System	--	3	1	6	10
Fox/Des Plaines/Kankakee	Kankakee - Iroquois River System	--	3	--	2	5
Illinois	Little Vermilion River, Big Bureau and Kickapoo Creek Systems	2	3	2	3	10
Illinois	Vermilion and Mazon River Systems	1	2	--	2	5
Illinois	Spoon River System	1	2	1	16	20
Illinois	La Moine River System	--	--	--	3	3
Illinois	Mackinaw River System	2	1	2	11	16
Illinois	Sangamon River System	2	3	--	13	18
Illinois	Lower Illinois River Tributaries and American Bottoms	6	3	--	8	17
Kaskaskia	Kaskaskia River System	3	5	2	38	48
Shawnee	Big Muddy River System	8	3	10	15	36
Shawnee	Cache River System	9	8	15	15	47
Shawnee	Massac, Bay, Lusk, Big Grand Pierre and Big Creek Systems	4	5	5	12	26
Shawnee	Saline River System	7	1	1	5	14
Wabash	Little Wabash River and Bonpas Creek Systems	7	1	3	32	43
Wabash	Embarras River and Wabash River Tributaries	2	--	2	18	22
Wabash	Vermilion and Little Vermilion River Systems	--	--	--	4	4
All units combined		54	113	150	356	673

[a] Data for 1900 through 1993 are from Anderson (1995).

[b] Population management units follow the delineation of Illinois stream systems by Page et al. (1992) with some modifications. Bluett et al. (1995) provided a more detailed description.

[c] Three observations occurred from 1 January through 21 January 1994, one from the Rock River System and two from the Galena, Apple and Plum River Systems.

Figure 1. River otter Landscape Management Units (LMUs) in Illinois as defined by Bluett et al. (1995).

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 79-87

received 2/25/98
accepted 11/5/98

Response of Largemouth Bass and Bluegill to Length Limits in Lake of Egypt

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ABSTRACT

Changes in proportional stock density, relative weight, age and growth, and survival rates of largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis machrochirus*) were evaluated in relation to various length limits placed on largemouth bass in a southern Illinois reservoir. Improvements of largemouth bass and bluegill populations occurred initially after a 356 mm (14-inch) minimum limit was placed on bass in 1983. A 406 mm (16-inch) minimum-length limit placed on bass in 1987 produced slow-growing bass in poor condition and a decrease in the condition of the bluegill. A slot limit on the largemouth bass would probably improve the growth rate and size structure of the bass and bluegill.

INTRODUCTION

Length limits are among the most widely used and valuable tools available to fishery managers for the protection and manipulation of freshwater game fishes (Wilde, 1997). In an attempt to produce or maintain quality largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) populations, fisheries managers have frequently used minimum-length and slot-length limits. The purpose of this study was to document the effects of largemouth bass length limits on the largemouth bass and bluegill populations in Lake of Egypt, Illinois.

In theory, minimum size limits lower angling and total mortality and reduce the exploitation of fish before they are sexually mature (Noble and Jones, 1993). Angler exploitation of a largemouth bass population can be quite high. Redmond (1974) reported 74% of largemouth bass larger than 229 mm were harvested from Pony Express Lake, Missouri, in the first nine months after the lake was opened to public fishing. Based upon his extensive review, Wilde (1997) concluded that length limits on largemouth bass populations resulted in mixed success. A bass population with high recruitment can be negatively affected by a minimum-size limit, while a bass population with high fishing pressure and low recruitment can be improved by a minimum-length limit (Van Horn et al.,

1981). Lindgren and Willis (1990) attributed the success of a 380 mm minimum length limit placed on largemouth bass in Lake Alvin, South Dakota, to naturally low recruitment and density of the largemouth bass population. Poor growth and size structure of largemouth bass under minimum-length limits have been frequently reported, and a change in the regulation to a slot-length limit improved the largemouth bass population (Dean, Jr. et al., 1991; Eder, 1984; Neumann et al., 1994). A slot limit has a protected length range where no fish may be harvested, but allows for the harvest of fish on either side of the protected range. Angler harvest below the lower limit of the slot reduces the surplus of recruits and allows the mid-size fish to grow out of the slot. For the slot limit to work, the surplus young fish must be harvested, and satisfactory growth rates must be sustained to allow fish to grow out of the slot (Noble and Jones, 1993).

LAKE DESCRIPTION AND METHODS

Lake of Egypt is a 931 ha man-made lake located in Williamson and Johnson counties, Illinois. The lake has a maximum depth of 15.8 m and was impounded in 1962 by Southern Illinois Power Cooperative to supply cooling water for a 300 megawatt fossil fuel electric power plant. In 1983, a 6 fish/day, 356 mm (14-inch) minimum length limit was placed on largemouth bass. In an attempt to produce more largemouth bass over 381 mm (15-inch) in 1987, the length limit was increased to a 406 mm (16-inch) minimum length limit with a 6 fish/day limit. Using AC electrofishing, largemouth bass were collected from Lake of Egypt in the fall of 1984 and 1985 and the spring of 1988, 1990, and 1994. In order to compare growth rates among years, fall collected fish were aged one year older, which assumes that they would not significantly increase their length from fall to January. Bluegill were also sampled in the spring or 1988, 1990, and 1994. All largemouth bass and bluegill were measured for total length to the nearest millimeter and weighed to the nearest gram. In addition, saggitae otoliths were removed for age and growth analysis.

The distance from the nucleus to the annuli was measured on a whole mount of one otolith, and the cross section of the other otolith was used to verify age of the whole mount. A straight line relationship with a zero intercept was used to back calculate the length of the fish at age from the otolith (Heidinger and Clodfelter, 1987).

Population size structure was assessed using proportional stock density (PSD) (Anderson, 1978), relative stock density (RSD) (Wege and Anderson, 1978), and length-frequency distributions. Approximate 95% confidence interval estimates for PSD and RSD were taken from tables calculated by Gustafson (1986).

Standard length-weight equations developed by Henson (1991) and Hillman (1982) were used to determine relative weight (Wt) of largemouth bass and bluegill. For largemouth bass, the minimum applicable total length is 150 mm, and for bluegill it is 80 mm. Incremental relative weight was calculated for four of the five categories developed by Gablehouse (1984). Gablehouse defined five progressively increasing length ranges as stock, quality, preferred, memorable, and trophy. We did not collect fish in the trophy category. Incremental relative weight is the mean relative weight between stock and quality size (S-Q), quality and preferred size (Q-P), preferred and memorable size (P-M), and memorable and trophy size (M-T). Each size category has a specific length for each

species. The corresponding sizes of largemouth bass for stock size is 200 mm, for quality size 300 mm, for preferred size 380 mm, for memorable size 510 mm, and for trophy size 630 mm. The stock size for bluegill is 80 mm, quality size is 150 mm, preferred size is 200 mm, memorable size is 250 mm, and trophy size is 300 mm (Gablehouse, 1984).

Confidence interval estimates were calculated by using the equation: confidence interval = mean relative weight times (1.96) (standard error) and are reported with all relative weight values. Survival was calculated using the method developed by Robson and Chapman (Ricker, 1975). All mean values calculated were compared with analysis of variance and Duncan's multiple range test (Zar, 1984).

RESULTS

Largemouth Bass

Gablehouse (1984) considered bass populations to be in balance when the PSD ranges from 40-70 and the RDS-380 range from 10-40. From 1984 to 1994, both PSD and RSD-380 values remained within these ranges (Table 1). The PSD (43) and RSD-380 (5) were both lowest in 1984, under the 356 mm (14-inch) minimum length limit implemented in 1983. Based on a mean relative weight of 95 and a growth rate at or above the average for bass from Illinois, forage appeared to be adequate (Tables 1 and 2).

By 1985, while still under the 356 mm (14-inch) length limit, the PSD value increased to a high of 64 and the RDS-380 value to a high of 20. Mean relative weights remained good at 97, and length at age continued to be above the state average (Tables 1 and 2). In 1987, a 406 mm (16-inch) minimum length limit was placed on the largemouth bass. In 1988, both the PSD (51) and the RSD-380 (14) were lower than the study high obtained in 1985 (Table 1). Mean relative weight fell to 90, but growth rates were still about the average for Illinois (Tables 1 and 2). Little change occurred in the PSD and RSD-380 from 1988 to 1990, but relative weights were lower (Table 1). By 1994, seven years after the 406 mm (16-inch) length limit was placed on the largemouth bass, the PSD (49) and RSD-380 (6) were very similar to those obtained in 1984 and lower than those obtained in 1985, 1988, and 1990. Mean relative weight (86) was the same as obtained in 1990 and significantly lower than in 1984, 1985 and 1986 (Table 1). Growth rates of largemouth bass were similar to the Illinois average from 1984 to 1990, but by 1994, except for age 2, the total length at age was less than the Illinois average (Table 2). By age 8, the largemouth bass were 120 mm less in total length than the Illinois average (Table 2). There was no evidence of stacking just below the length limit during any of the five sampling years (Figure 1).

Using the age-frequency method developed by Robson and Chapman, estimated survival was computed for largemouth bass in 1984, 1985, 1988, 1990, and 1994 (Ricker 1975). Estimated survival in 1984 for ages 2-5 was 54%. In 1985, the estimated survival increased slightly to 57% for ages 2-6. In 1988, the year after the implementation of the 16-inch minimum-length limit, estimated survival declined to 43% for ages 2-6. Estimated survival increased to 75% for ages 2-6 in 1990. In 1994, there was a decline to 64% for ages 2-6, while survival for ages 2-9 was 65%.

Bluegill

In 1988, the bluegill PSD of 22 was at the low end of the desired range of 20-40. In 1994 it had declined below the desired range to 16. RSD-200 was always low (Table 3). Mean relative weights of bluegill were lowest (87) in 1988, increased to a high of 99 in 1990, and then declined to 90 in 1994 (Table 3). In general, incremental relative weight of bluegill followed the same trend. Mean total length at age three and older bluegill were shorter in 1988 than in 1990 or 1994. The 1988 data were not available to statistically test the differences in age and growth among the three years. Bluegill lengths were significantly longer at ages 1-5 in 1990 than in 1994, the same at age 6, and shorter at age 7 (Table 3).

DISCUSSION

In general desirable population structure and condition of largemouth bass increased to their highest levels in 1985 under the 356 mm (14-inch) length limit and then declined. In 1990, under the 406 mm (16-inch) length limit, growth rates of bass had started to decline, and in 1994 there was a reduction in the number of larger bass and in overall bass plumpness. The lower growth rates in 1990 and 1994 correspond with higher survival in 1990 and 1994 than in 1984, 1985 and 1988.

The reduction in condition and growth rate is presumed to be the result of smaller size bass increasing their numbers and thus their demand for food. In 1988 survival of smaller size fish remained high and their condition continued to decrease which indicates vulnerable forage was limiting. Survival continued to remain high in 1990 and 1994 with few bass reaching the legal length limit. The bluegill population structure shifted toward smaller individuals from 1988 to 1994. The relative weight of bluegill increased from 1988 to 1990 and then decreased in 1994. Likewise, growth rates increased dramatically from 1988 to 1990 and then decreased from 1990 to 1994.

In his review of length limits Wilde (1997) concluded that minimum-length limits increased angler catch rates but did not usually increase proportional stock densities or relative weights of largemouth bass populations. Slot limits tend to restructure the bass population but neither tend to do both. Minimum-size limits are recommended for bass populations with good growth rates, high fishing, mortality, and low rates of recruitment (Anderson, 1980). A reduction in the quality of largemouth bass populations can be expected in eutrophic waters with minimum-length limits placed on largemouth bass. The high recruitment and low mortality of the bluegill and largemouth bass populations in Lake of Egypt resulted in low condition, slow growth, and poor population structure in less than four years.

The reduction in the quality of bluegill population corresponds to the reduction in the quality of the largemouth bass population. Evidently, not enough large bass were present to reduce the numbers of intermediate size bluegill so that the remaining bluegill would have sufficient food to grow rapidly.

When the size limit was changed in 1987 to a 406-mm minimum-length limit, the bass were just at the lower range of condition for a balanced bass population. By the early 1990's, the length limit needed to be altered to reduce the number of small bass and

increase the amount of prey available to the bass. In 1996, the limit was changed to a 2 bass less than 356 mm and 4 bass larger than 406 mm slot-length limit. The slot-length limit is designed to increase growth rates, condition, and population structure of the bass population by reducing the number of small bass below 356 mm while protecting the limited number of bass between 356 and 406 mm. The protected range allows those bass an opportunity to grow to a larger size. If anglers do not harvest bass below the slot, the slot-length limit will function as a 406-mm minimum-length limit and compound the problem. When length limits are used to manage largemouth bass and bluegill populations, the objective of the length limit needs to be clearly stated. The effect of the length limit should be monitored at least every two years. The classical stacking of bass just below the minimun-size limit did not occur in Lake of Egypt. Thus in some lakes it is necessary to supplement length-frequency data with relative weight and age and growth information in order to make the best management decisions.

ACKNOWLEDGMENTS

We thank Greg Conover, Mike Schmidt, Ron Brooks, and Jimmy Waddell for their assistance in collecting and analyzing data for this research project. This project was funded by the SIUC Cooperative Fisheries Research Laboratory.

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Table 1. Summary for population structure and condition for largemouth bass from 1984, 1985, 1988, 1990 and 1994 for Lake of Egypt, Illinois. Confidence intervals (95%) are included. Analysis of variance was used to test for significant differences among years with different letters denoting significant differences among years.

	1984	1985	1988	1990	1994
Length Limit (mm)	356	356	406	406	406
Population Structure					
PSD	43 (16)	64 (10)	51 (10)	52 (10)	49 (9)
RSD-380	5 (7)	20 (8)	14 (7)	15)7)	6 (4)
Condition					
Mean Wr[a]	95 (2) y	97 (2) z	90 (2) x	86 (2) w	86 (1) w
S-Q Wr[a]	93 (3) z	98 (2) z	89 (2) y	87 (4) x	87 (1) x
Q-P Wr[a]	96 (3) z	97 (2) z	88 (3) y	84 (3) y	84 (1) y
P-M Wr[b]	95 (7) zy	96 (2) z	93 (5) zy	85 (4) y	90 (4) zy
	94 (2) y	98 (2) z	90 (2) x	97 (3) w	86 (1) w
<406mm Wr[a]					
>406mm Wr	97 (3)	97 (3)	89 (5)	86 (3)	93 (4)

[a]p=0.0001
[b]p=0.0081

Table 2. Age and total length (mm) of largemouth bass collected from Lake of Egypt, Illinois, in 1984, 1985, 1988, 1990 and 1994.

Age	1984[b]	1985[b]	1988[a]	1990[a]	1994[a]	IL Average IDNR 19884
1	170	173	160	175	143	160
2	264	257	263	262	239	228
3	312	333	321	309	287	295
4	343	366	371	340	315	345
5	402	373	402	390	337	401
6		488	459	430	348	442
7				469	362	480
8				512	383	503

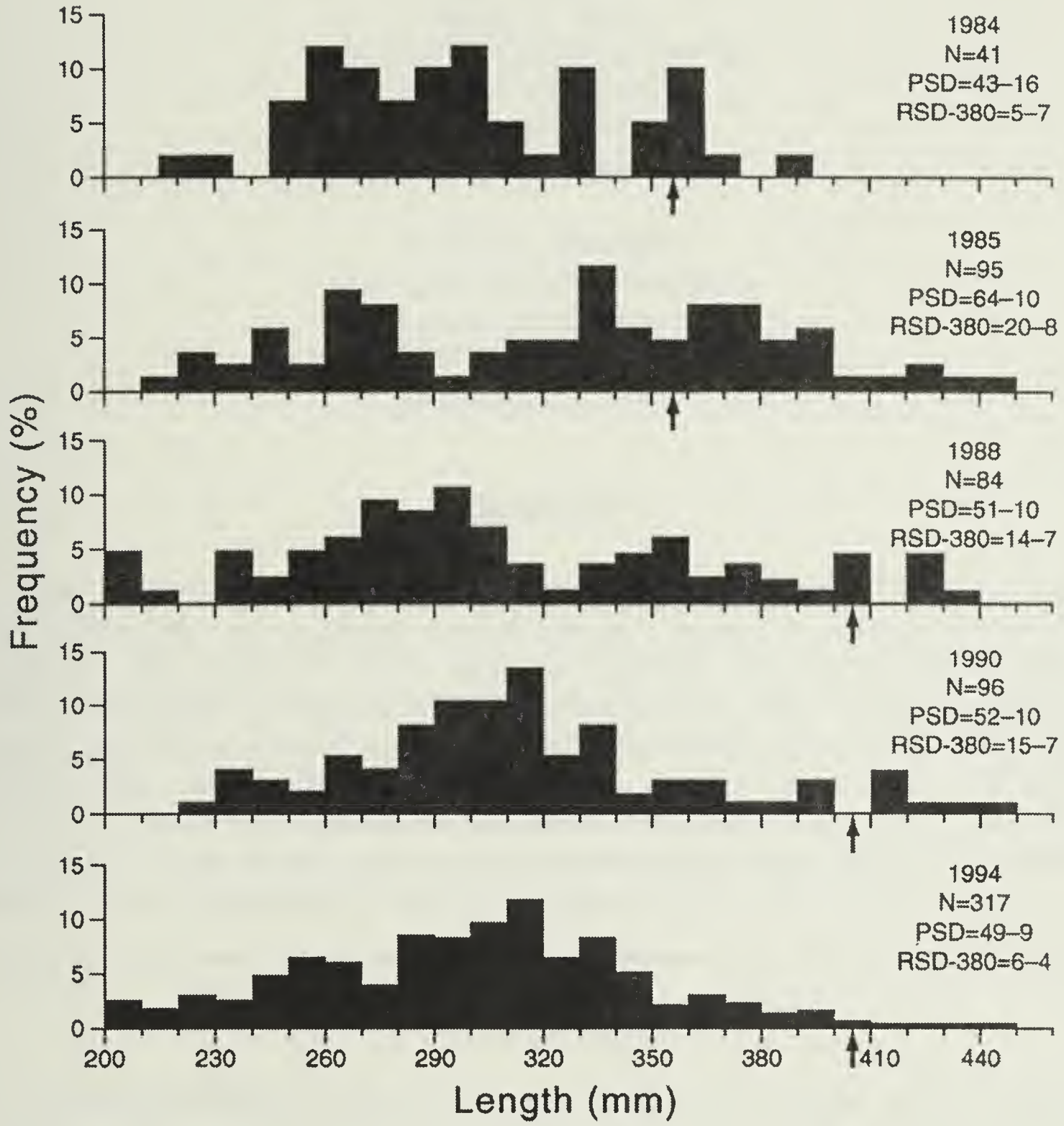
[a] Back-calculated age and growth from spring sample.
[b] Actual length at capture. These fish were collected in the fall; therefore, in order to make the data comparable, 1+, 2+, etc., fish in 1984 and 1985 were assigned an age of 2, 3, etc., respectively.

Table 3. Summary of population structure, condition, and mean back-calculated lengths for bluegill from 1988, 1990 and 1994 from Lake of Egypt, Illinois. Confidence intervals (95%) are included for PSD, RSD-200, and Wr values. Analysis of variance was used to test for significant differences among years for condition and mean back-calculated total length with different letters denoting significant differences among years. 1988 was not included in the statistical analysis for back-calculated total length.

	1988	1990	1994
Population Structure			
PSD	22 (7)		16 (6)
RSD-200	1 (4)		
Condition			
Mean Wr[a]	87 (2) x	99 (2) z	90 (1) y
S-Q Wr[a]	86 (2) x	97 (4) z	91 (1) y
Q-P Wr[a]	89 (2) y	100 (2) z	88 (2) y
P-M Wr	96	100 (7)	
Age	Back-Calculated Total Length (mm)		
1[a]	67	81 z	64 y
2[a]	96	113 z	93 y
3[a]	117	140 z	120 y
4[a]	128	160 z	146 y
5[b]	138	172 z	163 y
6	147	174 z	173 z
7[c]	145	164 z	180 z

[a] p=0.0001
[b] p=0.0148
[c] p=0.0270

Figure 1. Length-frequency distribution, proportional stock density (PSD-95% CI), and relative stock density (RSD-380-95% CI) of largemouth bass from Lake of Egypt, Illinois, in 1984, 1985, 1988, 1990, and 1994. Arrow indicates size limit.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 89-94

received 4/21/98
accepted 6/9/98

Food Contents of Mallard Gizzards With and Without Ingested Lead or Steel Shot

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ABSTRACT

The diets of hunter-harvested mallards (*Anas platyrhynchos*) taken throughout Illinois from 1979 to 1981 and containing ingested lead shot, ingested steel shot, or no shot were compared. This is the first known study to investigate whether free-ranging mallards mitigate the effects of lead exposure by adjusting their diets. Mallards containing ingested lead shot consumed significantly more plant matter ($P < 0.001$) and a higher number of plant species ($P < 0.001$) than controls. In addition, our results indicate ($P = 0.07$) that mallards with ingested lead shot were more likely to consume animal matter than controls. These findings agree with numerous dosing studies that have demonstrated the role of diet in alleviating the symptoms of lead poisoning in waterfowl.

INTRODUCTION

The ameliorating effects of diet and the rate of food consumption on the toxicity of ingested lead in waterfowl are well documented. Several investigations have reported the effects of diets on lead poisoning in waterfowl (Jordan and Bellrose 1951, Sanderson and Irwin 1976, Forbes and Sanderson 1978, Sanderson and Bellrose 1986). These investigations concluded that the amount of food, protein, calcium, and soil consumed may have some mitigating effects on the symptoms of lead poisoning in ducks dosed with lead shot. Jordan (1968) noted that when given a choice of food items, lead-poisoned birds shifted to items more easily digested. He suggested that lead-poisoned birds in the wild may select foods that tend to alleviate the effects of lead and thereby enhance their probability of surviving. Jordan and Bellrose (1951) concluded that diet rather than the level of shot dose was the more important variable in lead poisoning. Diet also had a major influence on the retention and erosion of lead pellets in the gizzards and the amount of lead retained in body tissues of mourning doves (*Zenaida macroura*) (Marn et al. 1988). However, to our knowledge, the diets of free-ranging wild ducks containing ingested lead or steel

pellets have not been examined. This study investigated whether wild mallards with ingested lead shot attempt to ameliorate the symptoms of lead exposure by modifying their diets.

METHODS

From 1979 to 1981, 9,300 hunter-harvested mallard gizzards were collected at 29 public and private sites throughout Illinois to document shot ingestion rates (Anderson and Havera 1989) and food habits (Havera 1998). Examination of gizzard contents by X ray (grit) and fluoroscopy (food) with visual verification, as described by Anderson and Havera (1989), revealed that 404 of the gizzards containing ingested lead shot pellets and 92 of those with ingested steel shot pellets also contained food. Steel (nontoxic) shot has been required for use in sport hunting of waterfowl in at least some areas of Illinois since 1977 (Anderson and Havera 1989). To investigate whether gizzard contents of mallards with ingested lead pellets or steel pellets differed from those without ingested pellets, an equal number of controls (404 for lead and 92 for steel) was selected randomly from those gizzards of harvested mallards taken on the same date and at the same location. This approach allowed for similar availability of food resources, which varied among weeks, years, and locations. Food contents of gizzards with lead shot were not directly compared with those that had steel shot because sample sizes from the same dates and areas were not sufficient.

The food contents were identified, measured by the use of the dry volumetric method (Rogers and Korschgen 1966; L.J. Korschgen, Mo. Dept. of Conserv., pers. commun.), and recorded to the nearest 0.01 ml; grit was measured to the nearest 0.1 ml (Havera 1998). The percent calcium content of grit from 75 randomly selected gizzards that contained ingested lead shot and their respective controls was determined by methods modified from Harper (1964) and Harper and Labisky (1964); the grit was dissolved in acid and a gravimetric procedure was used with inductively coupled argon-plasma emission spectroscopy.

Comparisons of food and grit contents (Table 1) between gizzards with ingested lead shot and their controls and gizzards that contained ingested steel shot and their controls were evaluated with Wilcoxon Signed Ranks Test. The percent calcium in grit in gizzards with ingested lead shot and their controls was compared by the use of the paired t-test (Wilkinson 1996). The aggregate volume of plant food and the percentage with animal food were compared for gizzards that contained ingested shot and their controls by use of the percent test (Sokal and Rohlf 1981:735). The level of statistical significance used was $P \leq 0.05$.

RESULTS AND DISCUSSION

There is evidence that the diet and body condition of hunter-harvested ducks may differ from those collected by researchers (Greenwood et al. 1986, Reinecke and Shaiffer 1988, Sheeley and Smith 1989, Dufour et al. 1993, Heitmeyer et al. 1993). Biases may also occur when contents from gizzards rather than from gullets (esophagi and proventriculi) are used to determine foods consumed by waterfowl (Perret 1962, Bartonek and Hickey 1969, Dirschl 1969, Swanson and Bartonek 1970). Although these shortcomings are of

major concern for food habits studies *per se*, we believe that gizzard contents from hunter-harvested birds are useable for our study objective of comparing relative food habits of mallards with and without ingested shot.

Of the various grit, plant, animal, and corn (*Zea mays*) variables compared, mallards with ingested lead shot consumed more plant matter ($P < 0.001$) and a higher number of plant species ($P < 0.001$) than their counterparts without ingested shot (Table 1). In addition, there was an indication ($P = 0.07$) that a higher percentage of them had eaten animal matter than their controls. There was no difference in the average volume of grit in gizzards with ingested lead shot and their controls. Although the average calcium content of grit in gizzards containing lead shot (0.183%) was higher than that for the control group (0.157%), the difference was not significant ($P = 0.25$). No difference in the amount of corn consumed was noted for mallards containing ingested lead shot.

The only significant difference between the diets of mallards with ingested steel shot and their controls was that the controls consumed more corn ($P = 0.03$). We can not explain the statistical or biological significance of this result other than speculating that either these control birds fed in cornfields with minimal hunting pressure and lower shot availability or perhaps that ducks with elevated iron levels from ingested steel shot for some reason chose more non-corn food.

A larger volume of plant matter (higher food intake) and a greater number of plant species in gizzards of mallards with ingested lead shot, in conjunction with an indication that more of these birds ingested animal matter (high in protein), suggest that wild mallards modify their diets to alleviate the symptoms of lead exposure and are consistent with the following findings from dosing studies.

The type of food consumed is probably the single most important factor affecting the toxicity level of ingested lead in waterfowl (Jordan and Bellrose 1951). Forbes and Sanderson (1978) remarked that the food consumed by waterfowl influenced the degree of lead poisoning through its nutritive content, binding capacity for lead, hardness and size, effect on acid secretion, and probably other factors. Sanderson and Irwin (1976) found that the diet of mallards apparently not only provided protection from lead after it was absorbed from the digestive tract, but diet also may have enhanced the excretion rate of lead. Stendell et al. (1979) concluded that diet had an important effect on the rate of uptake of lead in wing bones of mallards. Finley et al. (1976) reported that mallards dosed with one lead shot and maintained on a balanced diet may not accumulate extremely high lead levels in the kidney and liver. Jordan and Bellrose (1951) reported that birds maintaining a normal rate of food intake failed to show symptoms of lead poisoning and they suggested that the volume of food intake may be important in alleviating lead poisoning.

In several experiments with various kinds of foods, Jordan and Bellrose (1951) found that foods high in protein were most successful in alleviating lead toxicity. Natural food items mitigating lead poisoning included green foliage of aquatic plants, followed by small seeds, such as those of millets and smartweeds. Animal food was also beneficial whereas corn was the least beneficial. Sanderson and Irwin (1976), Finley et al. (1976), and Finley and Dieter (1978) noted increased toxicity of ingested lead in mallards fed a

corn diet. Chasko et al. (1984) determined that black ducks (*A. rubripes*) and mallards feeding on a variety of plant and animal foods were less susceptible to lead poisoning than those feeding on cereal grains. Koranda et al. (1979) noted that a high protein-calcium diet was important in mitigating the effects of lead in dosed mallards and that some aquatic plants were high in calcium content. Other studies have demonstrated the beneficial effects of protein or calcium in alleviating lead toxicosis in mallards (Godin 1967, Longcore et al. 1974, Clemens et al. 1975, Carlson and Nielsen 1985).

The use of lead shot for sport hunting of waterfowl was banned throughout the United States beginning in 1991. Unfortunately, spent lead shot will remain available in many wetlands into the foreseeable future. The encouragement of diverse and abundant plant and animal food resources on refuges, public hunting areas, and private clubs will help alleviate the impacts of lead exposure in waterfowl that ingest lead pellets. It is ironic that waterfowl may ultimately be the instruments that remove the last vestiges of lead shot from our nation's wetlands.

ACKNOWLEDGMENTS

Numerous Illinois Department of Natural Resources (IDNR) personnel, members and employees of duck hunting clubs, and private citizens collected gizzards. P.A. Brewer and G.E. Potts (IDNR) processed gizzards for ingested shot. R.L. Keen, Department of Veterinary Clinical Medicine, University of Illinois at Urbana-Champaign, performed the radiological work. G.A. Perkins, Illinois Natural History Survey (INHS), performed the food habit analyses and S.G. Wood and M.M. Georgi (INHS) determined the calcium content of grit samples. D.L. Swofford, J.D. Brawn, and A.P. Yetter (INHS) assisted with the statistical analyses. K.E. Roat (INHS) performed the word processing. F.C. Bellrose, J.M. Levengood, and G.C. Sanderson (INHS) reviewed the manuscript and C.E. Warwick (INHS) provided editorial assistance. The study was funded in part by Federal Aid in Wildlife Restoration Projects, W-43-R and W-88-R, with cooperation from IDNR—Division of Wildlife Resources, INHS, and the U.S. Fish and Wildlife Service, cooperating.

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Table 1. Characteristics of gizzard contents ($\bar{x} \pm SD$) of mallards with ingested lead shot, with ingested steel shot, or with no shot (controls). The gizzards were collected throughout Illinois during the hunting seasons, 1979–1981.

	Gizzards			
Characteristic	With lead shot (n=404)	Control (n=404)	With steel shot (n=92)	Control (n=92)
Volume of grit (ml)	2.16 ± 1.03	2.24 ± 0.83	2.21 ± 0.84	2.27 ± 1.03
Volume of plant matter (ml)	3.01 ± 2.22[A]	2.43 ± 1.83[A]	2.56 ± 2.19	2.84 ± 2.65
Volume of animal matter (ml)	0.04 ± 0.27	0.02 ± 0.19	<0.01	<0.01
Volume of corn (ml)	0.62 ± 1.52	0.75 ± 1.55	0.64 ± 1.51[B]	1.15 ± 2.55[B]
Aggregate volume of plant food in gizzards (%)	98.78	99.12	99.89	99.72
Percentage of plant food (%)	98.48 ± 9.12	98.94 ± 7.84	99.81 ± 0.73	98.63 ± 10.51
Number of plant species	4.3 ± 2.4[A]	3.7 ± 2.1[A]	3.6 ± 1.9	3.7 ± 2.3
Number of animal species	0.1± 0.5	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.3
Percentage of gizzards with animal food (%)	11.14[C]	7.43[C]	10.87	8.70

[A] $P < 0.001$
[B] $P = 0.03$
[C] $P = 0.07$

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 95-107

received 5/1/98
accepted 8/5/98

Summer Records and a Maternity Roost of the Southeastern Myotis (*Myotis austroriparius*) in Illinois

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ABSTRACT

Information was collected on the summer distribution of the state-endangered southeastern myotis (*Myotis austroriparius*) from 1985 through 1991. Mist netting was conducted at 53 sites in the 11 southernmost Illinois counties; in addition, four caves, 17 abandoned mines, and a quarry in southern Illinois were surveyed for bats during the summer. Netting resulted in 68 captures of southeastern myotis at three locations: in Alexander and Pope counties and along the Johnson/Pulaski county line. Captures of reproductively active females demonstrated that maternity colonies occur in Illinois. Members of a maternity colony were radio-tracked to their diurnal roost in a hollow-based tupelo gum (*Nyssa aquatica*) tree in Little Black Slough, Johnson County. This was the northernmost maternity roost found for this species and the first documented use of a roost site other than a cave or building by a southeastern myotis maternity colony.

INTRODUCTION

The southeastern myotis (*Myotis austroriparius*) is a species of the southeastern United States whose range extends from southern North Carolina down the Atlantic seaboard to the northern half of peninsular Florida, through the Gulf States to eastern Texas and southeastern Oklahoma, and up the Mississippi and lower Ohio River valleys to southern Illinois and Indiana (Jones and Manning 1989). This species is listed as endangered in Illinois (Illinois Endangered Species Protection Board 1994), Indiana (Indiana Department of Natural Resources 1993), and Kentucky (Kentucky State Nature Preserves Commission 1996), threatened in South Carolina (South Carolina Department of Natural

Resources 1997), a species of special concern in North Carolina (North Carolina Wildlife Resources Commission 1994), and a protected species in Alabama (Alabama Department of Conservation and Natural Resources 1997). The southeastern myotis also was formerly a Category 2 candidate for federal listing as a threatened or endangered species (U.S. Fish and Wildlife Service 1989).

The natural history of the southeastern myotis has been studied most intensively in Florida (e.g. Rice 1957, Foster et al. 1978, Zinn and Humphrey 1981, Hermanson and Wilkins 1986). Maternity colonies in Florida primarily use caves (Rice 1957, Humphrey and Gore 1992), but small colonies also have been found in buildings (Sherman 1930, Foster et al. 1978, Hermanson and Wilkins 1986). Southeastern myotis maternity roosts are almost unknown outside Florida; caves used by maternity colonies are located in southern Alabama (Best et al. 1992), western Kentucky (J.R. MacGregor, pers. comm., 1992), and southwestern Georgia (J.A. Gore, pers. comm., 1992). Maternity colonies are thought to roost in hollow trees or buildings in Louisiana (Lowery 1974), eastern Texas (Schmidly 1983), and caveless portions of Arkansas (Sealander and Heidt 1990). During summer most adult males roost apart from the maternity colonies in caves, buildings, culverts, and bridges (Humphrey and Gore 1992). In peninsular Florida and Louisiana southeastern myotis are active year-round and some individuals use culverts, bridges, storm sewers, buildings, and hollow trees as well as caves as winter roosts (Fargo 1929, Rice 1957, Lowery 1974, Humphrey and Gore 1992). Individuals roosting in a box culvert in Texas during the winter were not dormant (Walker et al. 1996) and bats have been observed emerging from caves in western Florida throughout the winter (Humphrey and Gore 1992). In northern parts of their range southeastern myotis hibernate for several months in caves or abandoned mines (Whitaker and Gammon 1988, Hoffmeister 1989, Sealander and Heidt 1990, Harvey et al. 1991).

Historical records for the southeastern myotis in Illinois are limited and, prior to the results reported here, the species had been documented at only eight (to ten) localities in four counties: Alexander, Hardin, Johnson, and Union (Hoffmeister 1989; Appendix). Smith and Parmalee (1954) reported the first Illinois specimens obtained from a cave and fluorspar mine in Hardin County during 1953, although the University of Illinois Museum of Natural History Mammal Collection [UIMNH] contains specimens collected in a Hardin County cave during 1950 (specimens originally identified as *M. grisescens*). Southeastern myotis in Illinois also have been found in abandoned silica mines (Illinois Natural History Survey Mammal Collection [INHS], Whitaker and Winter 1977). Prior to this study, the most recent confirmed records for this species in the state were from a 1974 bat survey of caves and mines on the Shawnee National Forest (Whitaker 1975, Whitaker and Winter 1977). Most of the records are of individuals collected or observed during late autumn and winter (October through March) and only males had been caught in the state during summer (Whitaker 1975, Hoffmeister 1989).

The Illinois Natural History Survey and Illinois Department of Conservation (now Department of Natural Resources), with support from the Illinois Department of Transportation, Shawnee National Forest (U.S. Forest Service), and U.S. Fish and Wildlife Service (Region 3), undertook a cooperative effort from 1985 through 1991 to determine the summer distribution and status of this species in southern Illinois. The capture of a lactating female southeastern myotis along the Cache River during July 1987 was the first

indication that a maternity colony occurred in the state. Accordingly, radio-tracking was conducted during the summers of 1989 and 1991 to find the roost site(s) of this colony and determine its foraging range.

METHODS

Mist Netting

The primary method used to determine the summer distribution of the southeastern bat was mist netting at surface sites in the 11 southernmost counties of Illinois: Alexander, Gallatin, Hardin, Jackson, Johnson, Massac, Pope, Pulaski, Saline, Union, and Williamson. Most of the netting sites were along perennial or intermittent streams or small rivers. Mist nets were placed at locations where overhanging branches of riparian trees formed a canopy above the stream or river channel; such a situation creates a tunnel through which bats fly to drink or feed on aquatic insects.

Bats were captured in black, 38-mm mesh, monofilament mist nets that ranged from 5.5 to 18.5 m in length and could be spread to a height of 2.2 m. A pair of metal poles either 6.1 or 9.2 m high was positioned under overhanging tree branches on opposite sides of the channel. Nets of equal length were stacked vertically and suspended above the stream or river between rope and pulley systems attached to the two poles (Gardner et al. 1989). Using these ropes it was possible to raise the top of the uppermost net to the canopy and block most of the flyway above the stream. An additional mist net frequently was spread across the channel just above water level to catch low-flying bats.

Mist netting was conducted from May through August on nights when environmental conditions were considered favorable (i.e. no precipitation or strong winds, limited moonlight, and temperatures above 9°C). Nets were raised at dusk and checked at 10- to 15-min intervals until 2400 h or later. Bats were removed from the net and examined to determine species, sex, age (juvenile or adult), and reproductive condition. Age class was determined by the degree of closure of the phalangeal epiphyses; juveniles (i.e. young of the year) are recognizable by the incomplete ossification of the epiphyses (Barbour and Davis 1969). The reproductive condition of males was assessed by the size of the epididymides; sexually mature males have enlarged or distended epididymides which can be seen through the interfemoral membrane (Racey 1988). Pregnant females were recognized by gently palpating the fetus through the abdomen, and lactating and post-lactating females by examination of the teats. Body weights were determined to the nearest 0.1 g with a Pesola spring scale. Southeastern myotis were color-banded for individual identification with a red or white sequentially-numbered, size XCL, celluloid split-ring band (A.C. Hughes, Hampton Hill, Middlesex, U.K.) on one forearm (right forearm for males, left for females).

Cave/mine Survey

Caves and abandoned silica and fluorspar mines in four southern Illinois counties (Alexander, Hardin, Johnson, and Union) with historical records for the southeastern myotis were visited during summer (May through August) to determine if they were used by this species. Bats also were captured at a Hardin County cave during 1985 and 1986 using a portable harp trap similar to one described by Tidemann and Woodside (1978). After the trap had been positioned in the cave's entrance, coarse nylon netting was used to cover

the remainder of the entrance and direct emerging bats into the trap. The trap was checked periodically from dusk until bats were no longer emerging from the cave.

Radiotelemetry

Radiotelemetry studies were conducted near the Cache River in Johnson and Pulaski counties. Radio transmitters were attached to selected southeastern myotis captured at the river as soon as the bat had been removed from the net and examined. Series BD-2A transmitters emitting unique frequencies between 172.0 and 173.0 Mhz (Holohil Systems Ltd., Woodlawn, Ontario, Canada) were used. These transmitters measure 12 x 8 x 4 mm, are equipped with a 11-cm long whip antenna, and weigh 0.68 to 0.80 g. Non-toxic medical cement (Smith+Nephew United Inc., Largo, Florida) was used to attach a transmitter to a bat's mid-sagittal dorsal surface just posterior to the scapulae after the hair in that area had been clipped. The bat was released as soon as the transmitter was attached firmly and the signal from the transmitter had been tested.

Bats were tracked using model TRX-1000S receivers (Wildlife Materials Inc., Carbondale, IL) and collapsible, three-element Yagi antennas (AF Antronics Inc., White Heath, IL). Attempts to track the bats to their diurnal roost site(s) involved covering an area within approximately 8 km of the capture site by vehicle, on foot, or by boat during the daytime. In 1989 an attempt to delineate the bats' foraging range by taking a series of simultaneous readings from three fixed radio-tracking stations established on hilltops in the study area was unsuccessful because only sporadic signals were received. Limited information on foraging locations was obtained by monitoring signals at night from various locations in the study area.

RESULTS AND DISCUSSION

Mist netting was conducted for 86 nights at 53 sites in 11 southern Illinois counties during the summers of 1985 through 1991 (Figure 1). There were 598 captures of bats during this period, representing all 12 species that occur in Illinois. Sixty-eight captures (11.4%) were of southeastern myotis; this species was caught at three surface locations (Figure 2, Table 1). Four caves, 17 abandoned mines, and a quarry (containing a remnant of a natural cave) were surveyed for bats during summer (Figure 1); seven other mine entrances were located, but the shafts were collapsed or flooded. No southeastern myotis were found roosting in any underground sites.

The results of this survey suggest that three maternity colonies of southeastern myotis are present in southern Illinois. Three adult males and a lactating female were netted along Big Grand Pierre Creek (near IL Route 146) in Pope County in July 1988 and a lactating female was caught at Black Creek (near Horseshoe Lake) in Alexander County in July 1991 (Table 1). These may represent relatively small or relict colonies. The remaining 63 captures (39 adult females, ten adult males, and 14 juveniles) occurred at two net sites on the Cache River along the Johnson/Pulaski county line; southeastern myotis were netted in this area during the summers of 1987, 1988, 1989, and 1991 (Table 1). These captures, however, actually may not represent 63 individual bats. Three bats caught during 1987 were not banded and could have been captured during a subsequent summer and three bats that were not banded during 1989 could have been caught later that summer or

during 1991. It is also possible that an individual could have lost its band and been recaptured during a subsequent year. Nonetheless, it is apparent that a maternity colony composed of numerous southeastern myotis females roosted in the vicinity of the Cache River capture sites. Eleven adult females were caught there on two consecutive nights during May 1988 and 16 reproductively active females were caught during the summer of 1989.

These were the first female southeastern myotis known to have been captured in Illinois during summer. Of the few males that had been recorded during spring and summer, all but one were from a single location, Cave Spring Cave in Hardin County. Three males were collected there in late May 1959, six were collected in early August 1950, and seven were mist-netted in late August 1974 (UIMNH, Whitaker 1975). During this study, however, no southeastern myotis were trapped at Cave Spring Cave in 1985 or 1986. The remaining male was collected in an abandoned silica mine in Alexander County in April 1954 (INHS). Two additional southeastern myotis were observed or captured during late August 1974 at Rich's Cave in Union County and an active fluorspar mine in Hardin County, but the sex of these individuals was not reported (Whitaker 1975).

Bats in the Illinois maternity colonies spend the summer close to known and potential hibernation sites. Similarly, southeastern myotis in Florida did not appear to travel long distances between winter and summer roost sites (Rice 1957). The Black Creek location is within 20 km of abandoned silica mines in Alexander and southern Union counties. Neither Layne (1958) nor Pearson (1962) found southeastern myotis in silica mines, but a male collected in an Alexander County mine in early April 1954 (INHS) may have hibernated there and a hibernating individual was found in a Union County mine (Whitaker and Winter 1977). Two southeastern myotis also have been found hibernating in Rich's Cave (Layne 1958, Whitaker and Winter 1977), 45 km north of Black Creek. The Cache River sites are only 4.7 km from Whitehill Quarry where 23 specimens were collected in February 1960 (UIMNH, Southern Illinois University at Carbondale Mammal Collection [SIC]). During the winters of 1988 through 1991 between two and 220 southeastern myotis were censused in a remnant of a natural cave in an abandoned portion of the quarry (Gardner et al. 1992). The Big Grand Pierre Creek site is near several caves in Pope and Hardin counties as well as fluorspar mines in Hardin County. There are historical winter records for Cave Spring Cave, Layoff Cave, and fluorspar mines (Smith and Parmalee 1954; Layne 1958; W.H. Davis, cited in Whitaker and Winter 1977; UIMNH; SIC) and recent sightings in one cave each in Pope (1993) and Hardin (1998) counties (Illinois Natural Heritage Database, Illinois Department of Natural Resources, Division of Natural Heritage).

The captures of reproductively active females and juveniles (Table 1) supplement the limited reproductive data available for this species, most of which is from Florida. Parturition in Florida appears to occur from the end of April until late May, with a peak during the second week of May (Rice 1957, Sherman 1930, Foster et al. 1978) and Caire et al. (1989) speculated that parturition in Oklahoma occurs during mid-May. Rice (1957) thought that because of the latitudinal difference southeastern myotis females in Illinois and Indiana would give birth during late June. All 11 females captured at the Cache River on 4 and 5 May 1988 were pregnant; this suggests that parturition could have occurred as early as mid-May. In 1989 three females were lactating on 30 May, probably

having given birth during May, whereas two others were lactating on 14 and 15 July and may not have given birth until June. A female was lactating on 15 May 1991, an indication that parturition had begun by mid-May that year. All seven females caught on 15 and 16 July 1991 were post-lactating and 13 juveniles also were captured on those dates. Southeastern myotis become volant five to six weeks after birth (Rice 1957); thus it appears that these young were born in early June at the latest. Females from Alexander and Pope counties were lactating in early July; the adult female caught at the Cache River in 1987 was lactating in mid-July, but a juvenile also was captured at that time. These limited data suggest that parturition in southern Illinois typically occurs from mid-May through early June.

Radio transmitters were attached to 21 southeastern myotis caught at the Cache River. Transmitters were placed on a lactating female in July 1987, eight lactating females and two adult males during 1989, and one lactating female, four post-lactating females, and five juveniles (four females, one male) during 1991. In addition, the lactating female southeastern myotis netted in Alexander County was fitted with a transmitter in July 1991. In all cases the transmitter weighed < 12% of the bat's body mass and the mean holding time for 20 bats was 55 min (range: 28-103 min). Only three individuals displayed any difficulty flying away when released, but any added weight decreases a bat's maneuverability during flight (Aldridge and Brigham 1988).

On 1 June 1989 a diurnal roost used by two radio-tagged lactating females was discovered. The roost was a live tupelo gum (*Nyssa aquatica*) tree (Figure 3) in Little Black Slough, a bald cypress (*Taxodium distichum*) and tupelo gum swamp in Johnson County. The tree was surrounded by water, was located approximately 85 m from the edge of the slough, and had a diameter at breast height of 105 cm. A triangular opening 60 cm high and 25 cm wide (measured at water level) on the south side of its base led into a cavity that was 1.6 m in diameter at water level and extended upward for at least 6 m. A smaller, more circular opening (16 cm high x 30 cm wide) occurred on the west side of the trunk near water level. Canopy cover in the vicinity of the roost tree was visually estimated at 35% and the understory was sparse. This tree was the northernmost maternity roost documented for the southeastern myotis and the first roost site other than a cave or building known to be used by a maternity colony of this species. Rice (1957) had predicted that caves in Illinois and Indiana, which are 5° to 11°C cooler than Florida caves, might not be suitable roosts for southeastern myotis maternity colonies.

One hundred one southeastern myotis were counted as they exited this roost tree through the triangular opening at dusk on 15 June 1989. Subsequently, the water level in Little Black Slough rose and the tree had been abandoned by 18 July 1989. Because the openings are at the base of the tree, alternate roost sites must be available for the maternity colony to use during periods of high water. Members of the colony may have moved to another of the many hollow trees in Little Black Slough. When the roost tree was examined on 25 July 1990, at least 75 southeastern myotis were observed. The bats became agitated and a post-lactating female was captured as she tried to exit. This was an indication of roost fidelity on the part of the maternity colony. No bats occupied the tree on 16 May 1991 when high water again covered most of the openings.

Despite extensive efforts (driving and walking through the study area with receivers for several days following the attachment of transmitters) no other radio-tagged members of the Cache River population were tracked to a diurnal roost. Likewise no roost was found for the radio-tagged female caught near Horseshoe Lake although that area was thoroughly covered by car and boat. Signals were never received from some transmitters during the daytime and only occasional signals from others were detected. Possible reasons for this lack of success include bats roosting at great distances from their foraging areas, bats roosting underground or in man-made structures that blocked signal transmission, loss or malfunctioning of the transmitters (two were known to have become detached), decreased survival of bats fitted with transmitters, and hilly terrain interfering with signal transmission.

The straight-line distance between the roost tree in Little Black Slough and the site on the Cache River where the two radio-tagged females had been captured was 5.7 km. After these lactating females were fitted with transmitters they foraged along the Cache River both downstream and upstream of the capture site and along the Post Creek Cutoff (a large, channelized drainage ditch upstream of the capture site). They were detected at a location along the Cutoff that was 3.2 km from the capture site and 8.7 km from the roost tree. The movements of these individuals suggest that southeastern myotis cover large distances while foraging, especially as the added weight of the transmitters may have restricted their foraging range.

In summary, this study demonstrated that maternity colonies of southeastern myotis occur in Illinois, located the northernmost maternity roost for this species, and revealed the first documented use of a roost site other than a cave or building by a southeastern myotis maternity colony.

ACKNOWLEDGMENTS

This project was conducted under Memorandum of Understanding E-10-1 between the Illinois Natural History Survey (INHS) and Illinois Department of Conservation. Support was provided by Federal Aid in Endangered Species Act funds, U.S. Fish and Wildlife Service project E-10-1; Bureau of Design and Environment, Illinois Department of Transportation; and Supplement No. 4, Challenge Cost-Share agreement between the INHS and Shawnee National Forest. Many people assisted with field work in southern Illinois; we especially acknowledge the contributions of Rebecca (Beccy) Porter, Randall Collins, Raymond Smith, and Shawn Robinson. Valuable support also was provided by Mike Spanel, K. Andrew West, Lawrence Stritch, and the late Todd Fink. Rickard Toomey (Illinois State Museum), William Stanley (Field Museum of Natural History), George Feldhamer (Southern Illinois University-Carbondale), Laurie Wilkins (Florida Museum of Natural History), and James N. Layne supplied information about specimens. Figures for this paper were produced by Kate Hunter (INHS), using the Illinois Geographic Information System.

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Table 1. Capture data for southeastern myotis (*Myotis austroriparius*) in southern Illinois, 1985-1991. PG = pregnant female, L = lactating female, PL = post-lactating female, NR = non-reproductive adult female, AM = adult male, JM = juvenile male, JF = juvenile female.

Location	Year	PG	L	PL	NR	AM	JM	JF
Pope Co.								
Big Grand Pierre Creek	1988		1			3		
Alexander Co.								
Black Creek	1991		1					
Johnson/Pulaski Cos.								
Cache River	1987		1		2			1
	1988	11				4		
	1989		14	2	1	6		
	1991		1	7			6	7

Figure 1. Location of mist netting sites and summer cave/mine surveys, 1985 – 1991.

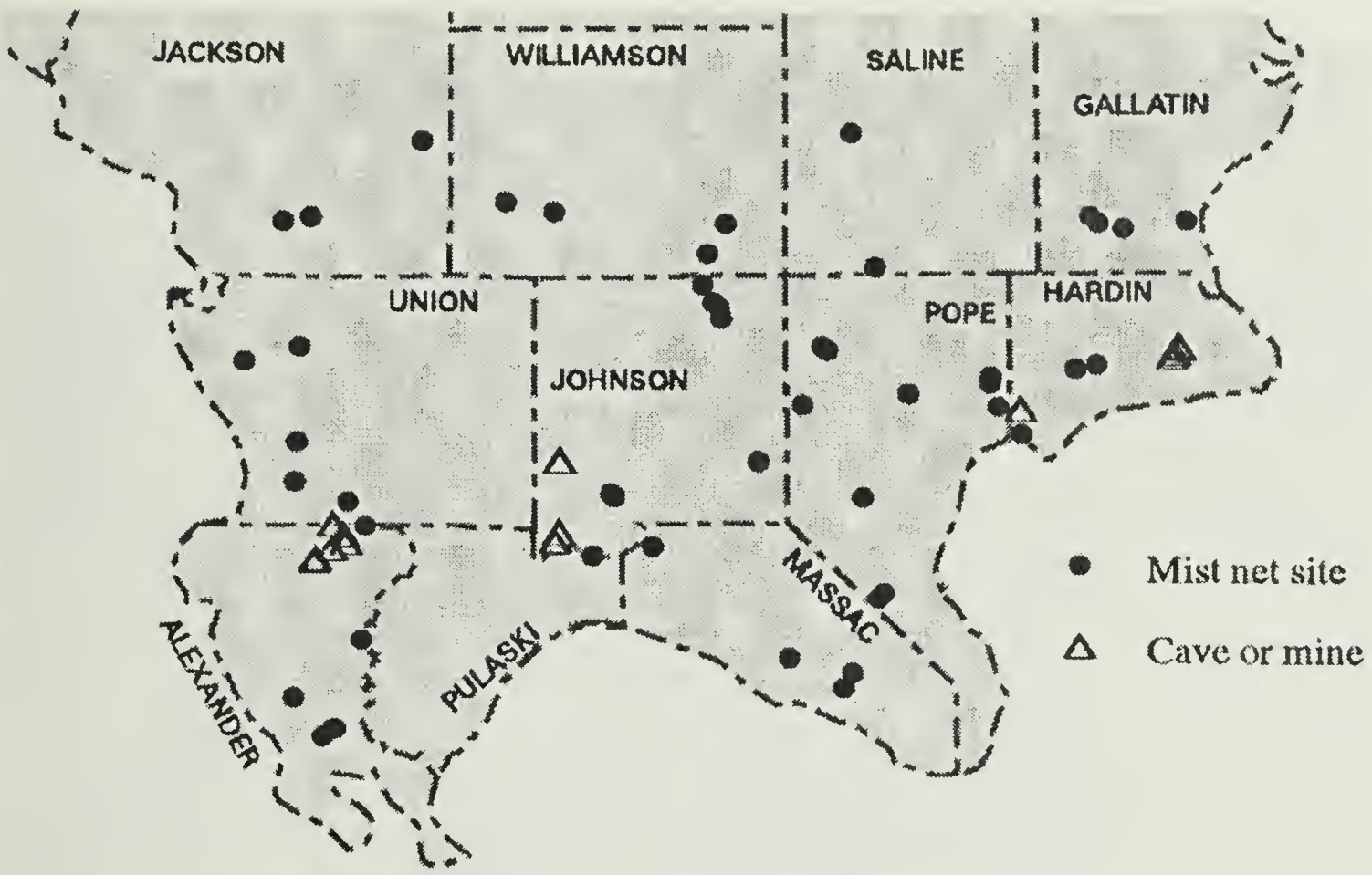

Figure 2. Summer records for southeastern myotis (*Myotis austroriparius*), 1985 – 1991, and location of roost tree used by maternity colony.

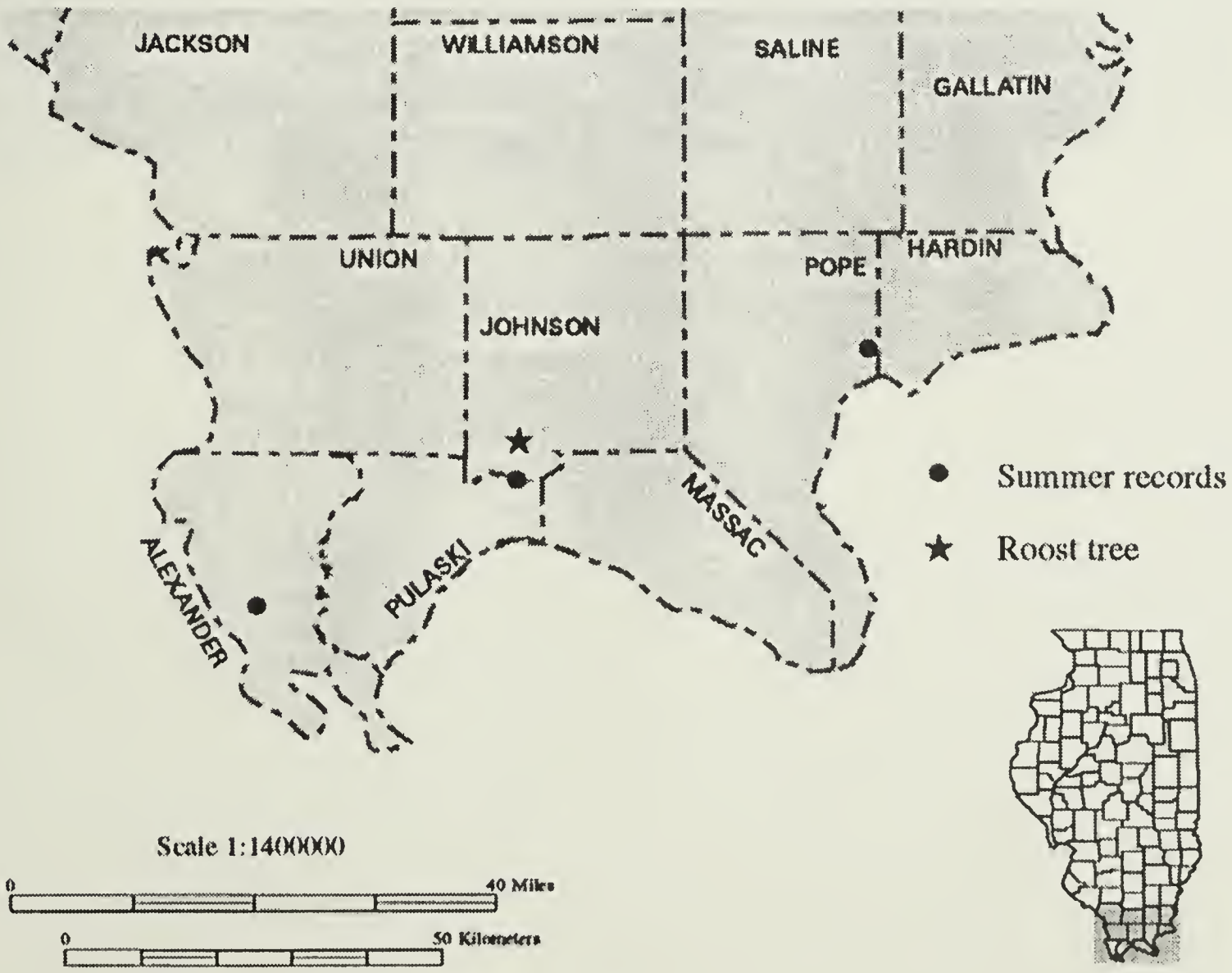

Figure 3. Tupelo gum (*Nyssa aquatica*) in Little Black Slough, Johnson County, Illinois used as a roost by a maternity colony of southeastern myotis (*Myotis austroriparius*)

APPENDIX

Historical records of southeastern myotis (*Myotis austroriparius*) in Illinois

County	Location	Date	Source(s)
Alexander	silica mine, 0.5 mi N Olive Branch	1954	INHS
Hardin	Cave Spring Cave	1950	UIMNH
	Cave Spring Cave	1953	cited in 5
	Cave Spring Cave	1954	3, FL
	Cave Spring Cave	1959	UIMNH
	Cave Spring Cave	1974	5
Hardin	Layoff Cave	1953	1, INHS, ISM, UIMNH, FM
	Layoff Cave	1954	3, SIC, FL
	Layoff Cave	1955	3, FL
	Layoff Cave	1956	SIC
Hardin	Griffith Cave	?	2
Hardin	fluorspar mine, 2.5 mi NW Cave in Rock	1953	1, INHS
	Crystal Mine #66	1974	4
	Mine 8 (exact location unknown)	1960	SIC
Johnson	Whitehill Quarry	1960	UIMNH, SIC
Union	Rich's Cave	1955	3, FL
	Rich's Cave	1974	4, 5
Union	silica mine #40	1974	5

Sources: 1 = Smith and Parmalee (1954); 2 = Rice (1955); 3 = Layne (1958); 4 = Whitaker (1975); 5 = Whitaker and Winter (1977); UIMNH = University of Illinois Museum of Natural History Mammal Collection; INHS = Illinois Natural History Survey Mammal Collection; SIC = Southern Illinois University at Carbondale Mammal Collection; ISM = Illinois State Museum Mammal Collection; FM = Field Museum of Natural History Mammal Collection; FL = Florida Museum of Natural History Mammal Collection

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 109-131

received 3/3/98
accepted 10/14/98

Habitat/Area Relationships, Abundance, and Composition of Bird Communities in 3 Grassland Types

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ABSTRACT

Habitat/area relationships, distribution, abundance, and composition of grassland bird communities were determined for 21 grassland fragments of 3 grassland types: fescue fields, mixed grass fields, and grass/forb fields. Fescue fields had 3-6 grassland bird species, mixed grass fields had 2-5, and grass/forb fields had 3-7. Henslow's sparrows and grasshopper sparrows were found only in fields >16 ha. Bobolinks, eastern meadowlarks, and red-winged blackbirds comprised 65-85% of the bird communities in all 3 habitat types. Numbers of grassland bird species were positively correlated with the size of fescue fields and the fescue-dominated grass/forb field, but negatively correlated for timothy-dominated grass/forb fields.

INTRODUCTION

For maximum biodiversity in grasslands, some of them should be large for area-sensitive species of birds. Unlike shrubland, woodland, or closed-forest ecosystems, where the native consumers are generally less mobile, grassland ecosystems support highly mobile wildlife species, because their food, water, and cover are more variably impacted by weather patterns and climatic extremes (Risser 1988). Essential patch sizes and shapes vary considerably among birds occupying grasslands (Herkert 1994, Vickery et al. 1994). Proximity of patches to each other also is important in determining presence or absence of a species. For example, greater prairie chickens (*Tympanuchus cupido*) need patches of 300 ha within 14 km of each other (Samson 1980). At least 4,000 ha of suitable habitat might be needed to support an isolated population of sharp-tailed grouse (*T. phasianellus*) in Wisconsin (Temple 1992). Of all bird species breeding on tallgrass prairies, nearly 67% are habitat-size-dependent (Samson 1980). Herkert (1994) found 5 (33%) area-sensitive bird species in Illinois grasslands.

Large areas of grassland habitat throughout the United States have become unavailable to wildlife due to intensive agricultural practices and increased urbanization. Federal Breeding Bird Survey (BBS) data and the National Audubon Society Blue List, among others, reported declines of grassland songbirds by 84-98% since 1957-1958 in northern and central Illinois (Anonymous 1983, Robbins et al. 1986, Tate 1986, Bohlen 1989, Herkert 1994).

Over 8.1 million ha of tallgrass prairie once covered 60% of Illinois. By 1970 <1% of that remained in scattered parcels throughout the state (Anderson 1970); <1000 ha of high quality prairie habitat remains (Iverson 1988). Meadows and hayfields that replaced native prairie declined substantially in area due to intensification of row crop farming, mainly corn and soybeans, since the late 1950's, and the loss of federal farm assistance programs such as the Soil Bank (Warner 1981, 1994, Herkert et al. 1996). As a result, habitat management of grassland areas controlled by public and private agencies is becoming increasingly important to preserve grassland birds in Illinois and elsewhere (e.g., Sample and Mossman 1997, Payne 1998, Payne and Bryant 1998). Grassland habitat produced by the federal Conservation Reserve Program has been beneficial, but the benefits will cease for wildlife if the CRP ceases (Patterson and Best 1996).

Opportunities to observe birds in native grasslands are scarce (Johnsgard and Rickard 1957), especially in Illinois where the associations of native tallgrass prairie used by grassland birds were not studied before the prairies were plowed (Birkenholz 1973). As a result, descriptions of habitats used by grassland birds in Illinois (e.g., Graber and Graber 1963, Bohlen 1989) and many other states have been limited mostly to pastures and hay-fields, as these usually are the only remaining extensive grassland habitats. Many studies have focused on the behavior and social organization of specific species of grassland birds, but few have examined species' habitat or area requirements (e.g., Frawley and Best 1991, Herkert et al. 1993, Herkert 1994, Herkert et al. 1996, Vickery et al. 1994, Warner 1994, Patterson and Best 1996).

Objectives of this study were to determine (1) differences in vegetative structure among 3 grassland habitat types, (2) bird species diversity relative to 3 grassland habitat types, and (3) the relationship between habitat size and bird species diversity and abundance in 3 grassland habitat types.

STUDY AREA

The study was conducted in the Forest Preserve District of DuPage County, IL. Located in northeastern Illinois about 32 km west of Chicago, and within the Northeastern Morainal Division (Mapes 1979, Neely and Heister 1987), DuPage County is a heavily urbanized county of 847 km^2. Presettlement vegetation in the county was 75% tallgrass prairie and wetland and 25% small savannas and groves timbered by widely scattered oaks (*Quercus* spp.) and hickories (*Carya* spp.) (Lampa 1985).

Within the District, non-native grasslands comprise 3035 ha created by seeding former croplands to perennial grasses,viz., meadow fescue (*Festuca elatior*) and white clover (*Trifolium repens*) before 1979, and a seed mixture of timothy (*Phleum pratense*), peren-

nial rye (*Lolium perenne*), and white clover since 1979, because they are less resistant to successional change than fescue is.

Three habitat types--fescue, mixed grasses, grass/forb--were selected for this study on the basis of plant species composition and percent coverage of the dominant grass and forb species.

Fescue Fields

Fescue fields consisted mainly of 80-95% coverage of meadow fescue interspersed with various forbs. Other grasses such as Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), quackgrass (*Agropyron repens*), smooth brome (*Bromus inermis*), reed canary grass (*Phalaris arundinacea*), and timothy were present in small percentages (≤5%).

Mixed Grass Fields

Mixed grass fields contained varying mixtures of fescue, timothy, Kentucky bluegrass, reed canary grass, smooth brome, orchard grass, quackgrass, and red top (*Agrostis alba*) interspersed with various forbs. Fescue and Kentucky bluegrass were the 2 main grass species in these mixtures. Coverage of grasses was 80-95%. The remaining grass species were present in larger percentages (5-20%) in this habitat type than in the fescue habitat type.

Grass/Forb Fields

Grass/forb fields contained mixtures of fescue, timothy, Kentucky bluegrass, reed canary grass, smooth brome, orchard grass, and quackgrass. Fields dominated by timothy were characterized by a dense coverage of forbs and other vegetation relative to the fields dominated by fescue. Half (4) of these fields contained stands mainly of timothy (24.3-97.1 ha) within mixtures of other grass species. Fescue was the dominant grass in the other 4 fields. Various forbs covered 25-40% of grass/forb fields. A few trees and shrubs such as willow (*Salix* spp.), eastern cottonwood (*Populus deltoides*), and multiflora rose (*Rosa multiflora*) usually were present, mainly in wet depressions and along fencerows. These woody species comprised <10% of the area of each field.

METHODS

A field was considered 1 sampling unit if it consisted of a single habitat type, and was not visually or physically divided by a barrier (e.g., fencerow, road). We assigned 21 fields, 8.9-97.1 ha, to 1 of 3 habitat types on the basis of plant species composition and percent coverage of the dominant grass and forb species. Eight fescue (8.9-87 ha), 5 mixed grasses (8.9-40.5 ha), and 8 grass/forb fields (8.9-97.1 ha) were sampled (Appendix I). Due to the excavation of artificial lakes, a fescue and a mixed grass field, each 40.5 ha, were sampled in 1986 but not in 1987.

Structural Characteristics of Grasslands

Vegetation measurements were taken during the breeding season (19 June-30 July 1986). Vegetation was sampled within 600 1-m^2 quadrats located randomly along bird transect routes (Oosting 1958, Weins 1969, Ohmann and Ream 1971). Transect lengths varied with the length of each field (Appendix I). A random numbers table was used to locate

30 quadrats 3-60 m on alternate sides of the bird transect line. Vegetation also was measured in quadrats surrounding identified bird nests and song posts.

The plant species, sociability, abundance, height, height density, and percent cover of grasses and forbs, standing and fallen litter, and bare ground were recorded within each quadrat. Sociability was determined by using the Braun-Blanquet sociability scale (Mueller-Dombois and Ellenberg 1974). Three representative heights for each plant species were taken within each quadrat. Six Daubenmire cover classes were used to estimate visually the percent of grasses, forbs, and bare ground (Barbour et al. 1980): 1 = 0-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-95%, 6 = 96-100%. All additional plant species observed within habitat types, but not occurring within quadrats, were recorded. Height-density was recorded as a measure of visual obstruction (Robel et al. 1970).

Discriminate function analysis with stepwise inclusion of variables (Klecka 1975) was used to determine the vegetation variables that statistically separated the 3 habitat types. Significance was set at the 0.05 level for all statistical tests. The Statistical Package for the Social Sciences (SPSS) computer program was used in the analyses. Twelve variables were selected for inclusion in the analysis: number of grass species, mean grass height, coverage of live grasses, coverage of dead grasses, total coverage of grasses, mean forb height, coverage of live forbs, coverage of dead forbs, total coverage of forbs, height density, litter depth, and bare ground coverage.

Bird Species Diversity

Bird surveys were conducted 3 times each year, from 28 May-17 June 1986 and 21 May-10 June 1987 to determine the presence of ≥ 90% of the breeding birds within the 3 field types (Kendeigh 1944). The physiognomy of fescue and timothy differs substantially, so the percent species composition of the bird community was calculated separately for fescue-dominated and timothy-dominated grass/forb fields. Fields usually were surveyed on successive days between 0530 and 1200 hours. Surveys were not conducted under conditions of poor visibility, fog, steady drizzle, prolonged rain, or when winds exceeded 19 kph (U.S. Fish and Wildlife Service 1972). The period between the 1st and 3rd bird surveys was always < 7 days.

Fields were surveyed for birds by walking straight line transects at about 20 m/min. Transects were located in the middle of fields to avoid counting birds using edge habitat. Bird species, sex (when distinguishable), and the number of individuals per species observed ≤ 60 m on each side of the transect line were recorded (Emlen 1971, 1977, Mikol 1980). Birds were identified with 10 x 50 binoculars, or by song.

Characteristic grassland breeding species were analyzed because they were widespread and numerous enough to determine if a relationship existed between the abundance (number of individuals) of each species and habitat type size. These species included bobolinks (*Dolichonyx oryzivorus*), eastern meadowlarks (*Sturnella magna*), red-winged blackbirds (*Agelaius phoeniceus*), savanna sparrows (*Passerculus sandwichensis*), and grasshopper sparrows (*Ammodramus savannarum*). Dickcissels (*Spiza americana*), Henslow's sparrows (*A. henslowii*), field sparrows (*Spizella pusilla*), and song sparrows (*Melospiza medodia*), found in only a few areas and in low numbers, were omitted from some analyses. Red-winged blackbirds were included because they were the most

numerous bird species during both years of the study and we wanted to see what affect their presence had on abundance and distribution of true grassland birds.

RESULTS

Structural Characteristics of Grasslands

We observed 61 herbaceous and 9 woody species of plants (Appendix II), with an average of 2.8 grass and 5.2 forb species in fescue fields, 5.2 grass and 9.0 forb species in mixed grass fields, and 5.0 grass and 9.6 forb species in grass/forb fields.

Fescue, Kentucky bluegrass, timothy, and smooth brome were the most common grass species within all habitat types. Commonly occurring forb species were Canada thistle (*Cirsium arvense*) and common milkweed (*Asclepia syrica*) (Table 1). We observed growth patterns (sociability) of 34 plant species occurring in our quadrats. Most (56%) plants observed grew singly. Fescue was the only plant species growing in large, almost pure stands (Table 2).

Discriminant analysis indicated that 9 of the habitat variables separated the 3 habitat types (Table 3). Two discriminant functions were derived by using these 9 habitat variables. The 1st discriminant function explained 74% of the variation in the data. The most important habitat variables separating the habitat types were grass height, height density, and bare ground. The 2nd discriminant function explained the additional 26% of the data variation, describing a separation between habitat types based on number of grass species and total cover of grasses. Number of grass species present, mean grass height, and total coverage of grasses best discriminated between habitat types, on the basis of the Wilks' Lamda values. Wilks' Lamda values ≥ 0.45 were considered to be significant based on the amount of separation between values.

Analysis of variance (ANOVA) showed that values for grass height, forb height, percent forb cover, percent bare ground, and height density were greater ($\underline{P}<0.05$) in the grass/forb habitat than in the other 2 habitat types (Table 4). Percent grass cover and litter depth were greater ($\underline{P}<0.05$) in the fescue habitat than in mixed grass or grass/forb habitat types (Table 4).

Forb cover, height density, and bare ground were greater ($\underline{P}<0.05$) on the timothy-dominated grass/forb sites than on fescue-dominated sites. Higher ($\underline{P}<0.05$) percent grass cover occurred in fescue-dominated grass/forb fields than in timothy-dominated fields (Table 4).

Bird Species Abundance and Composition

The 9 most common grassland bird species seen during the breeding season were red-winged blackbirds (1066), bobolinks (246), savanna sparrows (192), eastern meadowlarks (155), song sparrows (64), grasshopper sparrows (37), dickcissels (7), field sparrows (4), and Henslow's sparrows (2). Dickcissels and Henslow's sparrows were found only in the grass/forb fields. Dickcissels occurred in timothy-dominated fields, and Henslow's sparrows in fescue-dominated fields. Field sparrows were found within and next to fescue and mixed grass fields surrounded by trees and shrubs. Two of the 7 species of grassland birds studied most intently varied in their preference for vegetation characteris-

tics in the 3 grassland habitat types (compare Tables 4 and 5). Grass height, forb height, and height density were significantly greater for red-winged blackbirds than for the other 6 bird species, as were percent grass cover and percent bare ground for dickcissels.

We observed 22 other, mostly non-grassland bird species (Appendix III). Fifteen of the species were characteristic inhabitants of woodland edge areas, shrubby areas next to woodlands and fields, and suburban areas. Except for the northern harrier (*Circus cyaneus*), all are common breeding species in Illinois.

Bobolinks, eastern meadowlarks, savanna sparrows, grasshopper sparrows, red-winged blackbirds, and song sparrows occurred in all 3 habitat types (Figure 1). Bobolinks, eastern meadowlarks, and red-winged blackbirds, the 3 most ubiquitous grassland species, occurred in nearly all (90-100%) fields.

Red-winged blackbirds, bobolinks, and eastern meadowlarks comprised 65-85% of the bird communities in all 3 habitat types. Two or 3 species represented ≥75% of the total community structure in each habitat type (Figure 2). Savanna sparrows, red-winged blackbirds, and bobolinks predominated in fescue; bobolinks, eastern meadowlarks, and red-winged blackbirds in mixed grasses; and red-winged blackbirds and bobolinks in grass/forb. Dickcissels, grasshopper sparrows, field sparrows, song sparrows, and Henslow's sparrows each represented <10% of the bird community within any habitat type.

The grass/forb habitat contained a higher mean density (t-test, $P<0.05$) of birds/ha (0.62) than the fescue or mixed grass habitat types (0.40). Mean bird densities for 7 bird species were low (Table 6). Fescue fields contained higher densities of savanna sparrows and grasshopper sparrows than the other 2 habitats did. Mixed grasses fields contained higher densities of eastern meadowlarks. Grass/forb fields contained higher densities of bobolinks and red-winged blackbirds. Dickcissels and Henslow's sparrows were found only in grass/forb fields.

Bird Species and Habitat Area Relationships

Fields contained bird communities of 2-7 grassland species. Fescue fields had 3-6 (mean = 4.86±1.02) grassland bird species, mixed grasses had 2-5 (mean = 4.22±0.92), and grass/forb had 3-7 (mean = 4.93±1.29). Eight bird species (bobolink, eastern meadowlark, savanna sparrow, grasshopper sparrow, dickcissel, red-winged blackbird, Henslow's sparrow, song sparrow) occurred in grass/forb fields of medium size (27.9-52.6 ha).

Numbers of grassland bird species were positively correlated (log-log transformation) with the size of fescue fields ($r=0.51$, $P<0.05$) and the fescue-dominated grass/forb fields ($r=0.73$, $P<0.02$). Timothy-dominated grass/forb fields showed a negative correlation; all grass/forb fields combined showed no correlation. Eastern meadowlarks, savanna sparrows, and grasshopper sparrows showed strong positive correlation between the number of individuals and habitat area only in the fescue fields (Table 7). Bobolinks showed a positive correlation only in mixed grasses fields. Red-winged blackbirds exhibited a strong positive correlation in mixed grasses and grass/forb fields. Henslow's sparrows, grasshopper sparrows, and dickcissels were observed only in fields of >16 ha. Other bird species occurred in fields of all sizes (Table 7).

DISCUSSION

Structural Characteristics of Grasslands

Grasslands contain relatively homogeneous vegetation patterns which lack structural diversity, or patchiness, thus limiting the number of bird species that can exploit them (Roth 1976). Weins (1974) noted a general reduction in grass cover and litter depth and an increase in woody vegetation and bare ground cover with increases in plot heterogeneity. In our study, this condition was more pronounced in the grass/forb habitat type, where much heterogeneity was attributed to the presence of timothy. Timothy was prone to invasion by forbs, particularly Canada thistle, which reduced grass cover.

Height and density of vegetation were the factors that separated the 3 habitat types, and which separate grasslands in general. Different grass species and their growth patterns seem to be an important variable in the physiognomy of the habitat types. Growth patterns of the grass species present determined height of the vegetation, height density, amount of bare ground, and kinds of bird species present.

Bird Species Habit Area Relationships, Abundance, and Composition

In general, number of bird species seen in a given habitat increased as amount of habitat increased (Graber and Graber 1976, Nolin and Ritzenthaler 1987, Herkert 1994). Grasslands <10 ha in Illinois had only a few species of prairie birds breeding at low densities (Herkert 1991), and area requirements for 5 area-sensitive birds were 5 ha for eastern meadowlards, 30 ha for grasshopper sparrows, 40 ha for savanna sparrows, 50 ha for bobolinks, and 55 ha for Henslow's sparrows (Herkert 1994). Heckert et al. (1993) recommended that for birds the most sensitive to fragmentation, grasslands should be ≥ 50 ha and preferably >100 ha; area requirements of species might vary geographically (Herkert et al. 1996). Vickery et al. (1994) recommended ≥100 ha and preferably 200 ha. We found that only fescue and fescue-dominated grass/forb fields showed an increase in number of bird species with an increase in habitat size; timothy-dominated grass/forb fields showed a decrease. Samson (1980) found that Henslow's sparrows and grasshopper sparrows nested only in large grasslands. In our study these species were found only in fields >16 ha, suggesting that they might not breed in smaller fields.

Several bird species of grasslands and forests are rare or absent from many small, isolated habitat blocks, or even large blocks if they are too linear (e.g., Hagen and Johnson 1992, Heckert 1991, 1994, Herkert et al. 1993, Vickery et al. 1994, Payne and Bryant 1998), partly due to territorial needs (e.g., Robbins et al. 1989) and edge effects causing increased nest predation (e.g, Rudnicky and Hunter 1993, Burger et al. 1994, Paton 1994) and nest parasitism by brown-headed cowbirds (*Molothrus ater*) (e.g., Johnson and Temple 1990, Robinson et al. 1993, Bielefeldt and Rosenfield 1997, Niemuth and Boyce 1997). Evidently not all edges sustain predation rates higher than the interior (e.g., Burger et al. 1994). Habitat too isolated and small might not be able to sustain a viable population.

Structure and general abundance of the breeding bird community in perennial non-native grasslands in DuPage County, Illinois, were similar to those reported for grasslands by Graber and Graber (1963) in Illinois, Weins (1969) in Wisconsin, Birkenholz (1973) in Illinois, and Nolin and Ritzenthaler (1987) in Ohio. Graber and Graber (1963) found that

red-winged blackbirds represented 57% of the bird community, bobolinks 19%, and eastern meadowlarks 6%, which compares favorably with 54%, 22%, and 7%, respectively, found in similar habitat for these 3 species in our study.

An important characteristic of suitable habitat for red-winged blackbirds, which commonly nest in wetland and upland habitats (Robertson 1972), appears to be the presence of dense and sturdy vegetation for nest support. Several plant species in grass/forb fields, such as dogbane and thistles, provided such support. Zimmermann (1971, 1982) and Frawley and Best (1991) found that dickcissels also prefer habitats with sturdy forbs. Patterson and Best (1996) found that dickcissel abundance was correlated positively with percent forb cover and vertical vegetation cover. But Herkert (1994) found no relationship between numbers of dickcissels and either vegetation or area variables. Henslow's sparrows use grassland vegetation with patches of dense herbaceous vegetation and protruding weed stalks (Robins 1971); territorial males prefer areas with greater coverage by standing dead vegetation, lesser coverage by woody vegetation, and taller live grasses (Zimmerman 1988).

Fescue grasslands are generally classified as low heterogeneity, low diversity habitats that generally supply poor habitat to all but a few species of birds (Urbanek and Klimstra 1986, Nolin and Ritzenthaler 1987). In our study, fescue fields and fescue-dominated grass/forb fields contained higher densities of grasshopper sparrows, eastern meadowlarks, and savanna sparrows.

Nolin and Ritzenthaler (1987) considered timothy to be far superior habitat to fescue in Ohio. But we found that timothy contained few bird species, was prone to invasion by forbs and shrubs, and harbored predominantly red-winged blackbirds.

Grasslands contain relatively homogeneous vegetation patterns which lack structural diversity, or patchiness, and limit the number of bird species that can exploit them (Roth 1976). Grasslands also contain bird species with restricted habitat characteristics (Weins and Dyer 1975). The most common species in our study (bobolinks, eastern meadowlarks, and red-winged blackbirds) were observed in fields of all sizes. Bird diversity and density are low in grasslands compared to most other habitats (Cody 1985). Grassland bird communities tend to be dominated by 1 or 2 abundant widespread species (Graul 1980). In our study each habitat type contained 2 or 3 species that represented >75% of the bird community.

Densities of grassland birds were generally low in our study. Graber and Graber (1963) found greater density of birds in mixed hayfields (grass/forb) than in pastures (fescue and mixed grass). Densities from our study were substantially lower than those found by Graber and Graber (1963) in similar habitat. The lower population densities might be due partly to the loss of grassland habitat in Illinois and resulting decline in grassland bird populations and densities.

ACKNOWLEDGEMENTS

The Forest preserve District of DuPage County, IL and the Friends of the Furred and Feathered of DuPage County, IL provided funding. R. Rogers, of the College of Natural Resources, University of Wisconsin-Stevens Point, provided statistical advice.

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Table 1. Frequency of occurrence (%) of common plant species within 1-m^2 plots in northern Illinois, 1986. (No. of quadrats sampled is in parentheses.)

Plant species	Fescue (240)	Mixed grasses (150)	Grass/forb (240)
Grasses			
Fescue	98.3	83.1	38.7
Kentucky bluegrass	3.0	71.3	9.0
Smooth brome	3.0	6.0	15.4
Timothy	2.1	5.0	46.7
Quackgrass	1.2	5.0	12.9
Reed canary grass	< 1	2.0	4.0
Orchard grass	< 1	2.0	2.9
Forbs			
Canada thistle	11.2	7.3	28.7
Common milkweed	10.8	11.3	8.3
Queen-Anne's lace	2.9	5.0	4.6
Field bindweed	2.9	< 1	2.1
Common sow thistle	2.5	< 1	< 1
Hedge bindweed	2.1	4.0	1.4
Yellow sweet clover	< 1	2.0	5.8
Red clover	1.2	< 1	7.5
Alsike clover	< 1	< 1	7.9
Goldenrods	1.7	< 1	5.8

Table 2. Sociability of plant species based on the Braun-Blanquet Sociability Scale in northern Illinois, June-July 1986.

Plant species	Sociability rating[a]	Plant species	Sociability rating[a]
Meadow fescue	5	Evening primrose	1
Timothy	4	Sow thistle	4
Kentucky bluegrass	4	Dandelion	1
Smooth brome	2	Wild lettuces	1
Reed canary grass	2	Heal-all	1
Quackgrass	3	Peppermint	1
Redtop	1	Yarrow	1
Foxtails	4	Cinquefoils	3
Orchard grass	1	Dogbane	1
Canada thistle	4	Bull thistle	1
Yellow sweet clover	1	Daisy fleabane	1
White sweet clover	1	Lamb's quarters	1
Red clover	1	Pigweed	1
White clover	4	Common ragweed	2
Yellow hop clover	3	Field bindweed	1
Goldenrods	2	Hedge bindweed	1
Curled dock	1	Queen-Anne's lace	3

[a] 1=growing singly; 2=small but dense clumps; 3=small patches or cushions; 4=small colonies or carpets; 5=large, almost pure stands.

Table 3. Discriminant function coefficients for separating the 3 grassland habitat types (fescue, mixed grasses, and grass/forb) in northern Illinois, 1986.

Habitat feature	Discriminant functions[a]	
	1	2
Grass height	0.567	0.225
Number of grass species	-0.059	0.909
Grass cover	-0.358	0.585
Dead grass cover	0.244	0.346
Total grass cover	-0.326	-0.752
Forb height	-0.149	0.004
Dead forb cover	0.044	0.277
Height density	0.406	-0.040
Bare ground	0.365	0.119

[a] The 1st discriminant function explained 74% of the variation, the 2nd explained the other 26%.

Table 4. Mean values and standard deviations (SD) for vegetation characteristics of the fescue, mixed grasses, and grass/forb fields in northern Illinois, summer 1986.

					Grass/forb					
	Fescue		Mixed grasses		Fescue-dominated		Timothy-dominated		Combined	
Vegetable variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grass height (cm)	74.5	20.2	74.3	14.1	89.7	14.9	88.1	15.2	89.1*	15.1
Grass cover (%)	94.3*	5.4	94.7	5.1	92.6*	9.4	76.3	17.2	81.2	20.6
Forb height (cm)	54.1	19.2	51.3	20.2	59.7	18.2	58.5	20.6	59.7*	19.2
Forb cover (%)	11.2	15.3	12.3	13.6	15.5	14.8	31.3*	20.7	26.7*	24.3
Height density (dm)	2.1	0.7	2.2	0.5	3.2	1.3	3.5*	1.4	3.3*	1.3
Litter depth (cm)	4.7*	1.3	4.4	1.0	4.2	1.8	4.1	1.9	4.1	1.7
Bare ground (%)	5.2	2.3	4.6	1.7	5.9	2.1	19.4*	8.6	17.1*	10.8

* Significant at P=0.05 (ANOVA). For example, grass in the grass/forb fields was significantly higher than in the other 2 types of field.

Table 5. Vegetation characteristics selected[a] by 7 species of birds in 3 grassland habitat types (fescue, mixed grasses, and grass/forb) in northern Illinois, June - July 1987.

		Grass height (cm)		Forb height (cm)		Grass cover (%)		Forb cover (%)		Height density (dm)		Litter depth (cm)		Bare ground (%)	
Bird species	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Henslow's sparrow	9	84.0	5.4	65.2	20.2	87.3	8.2	18.4	12.2	3.2	0.5	8.4*	2.0	0.0	0.0
Grasshopper sparrow	16	64.3	19.6	44.2	14.7	74.7	19.4	28.4	17.9	1.8	0.8	3.8	1.5	21.2	4.3
Eastern meadowlark	30	68.4	9.6	36.5	11.0	96.6*	6.4	9.3	7.1	1.8	0.7	5.6	2.1	0.0	0.0
Savannah sparrow	24	74.6	16.6	52.2	19.8	89.5	11.2	15.3	13.7	2.4	1.0	4.6	1.5	16.2	3.4
Dickcissel	11	62.5	34.5	76.9	21.6	32.5	23.3	68.8*	15.3	3.8	1.6	2.2	2.4	25.3	6.2
Red-winged blackbird	37	93.4*	20.5	88.8*	23.6	59.3	23.1	47.2	24.4	4.3*	1.3	3.1	1.8	15.3	3.5
Bobolink	15	83.3	15.7	58.3	20.5	82.3	12.5	23.6	16.5	3.0	0.8	5.2	2.1	0.0	0.0

[a] N = sample size, i.e., number of nests or song posts around which vegetation was sampled. See Payne et al. (1998).

* Significant at P=0.05 (ANOVA pair-wise comparison using Bonferonni test). For example, litter was significantly deeper around nests and song posts in territories of Henslow's sparrows than in territories of other bird species.

Table 6. Calculated mean densities (birds/ha) and standard deviations (SD) for 7 bird species within 3 habitat types in northern Illinois, 1986 and 1987.

Species	Habitat type	N[a]	Mean	SD
Bobolink	Fescue	94	0.10	0.05
	Mixed grasses	48	0.11	0.04
	Grass/forb	79	0.15*	0.08
	Fescue-dominated	33	0.15	0.07
	Timothy-domintated	46	0.13	0.09
Eastern meadowlark	Fescue	66	0.07	0.02
	Mixed grasses	51	0.13*	0.05
	Grass/forb	38	0.06	0.04
	Fescue-dominated	27	0.09	0.03
	Timothy-domintated	11	0.03	0.02
Savannah sparrow	Fescue	131	0.14*	0.11
	Mixed grasses	15	0.08	0.03
	Grass/forb	22	0.05	0.06
Grasshopper sparrow	Fescue	24	0.04*	0.02
	Mixed grasses	2	0.03	0.00
	Grass/forb	10	0.04	0.02
Dickcissel	Grass/forb	7	0.04	0.02
Henslow's sparrow	Grass/forb	2	0.03	0.00
Red-winged blackbird	Fescue	57	0.06	0.04
	Mixed grasses	47	0.11	0.05
	Grass/forb	280	0.31*	0.17
	Fescue-dominated	60	0.19	0.13
	Timothy-domintated	220	0.43	0.11

[a] N = number of birds observed.

* Significant at P=0.05 (t-test). For example, the mean density of boblinks was significantly higher in grass/forb fields than in the other 2 types of field.

Table 7. Correlation coefficients (r) for habitat area (field size) with the number of individuals for each bird species in 3 grassland habitat types in northern Illinois, 1986 and 1987.

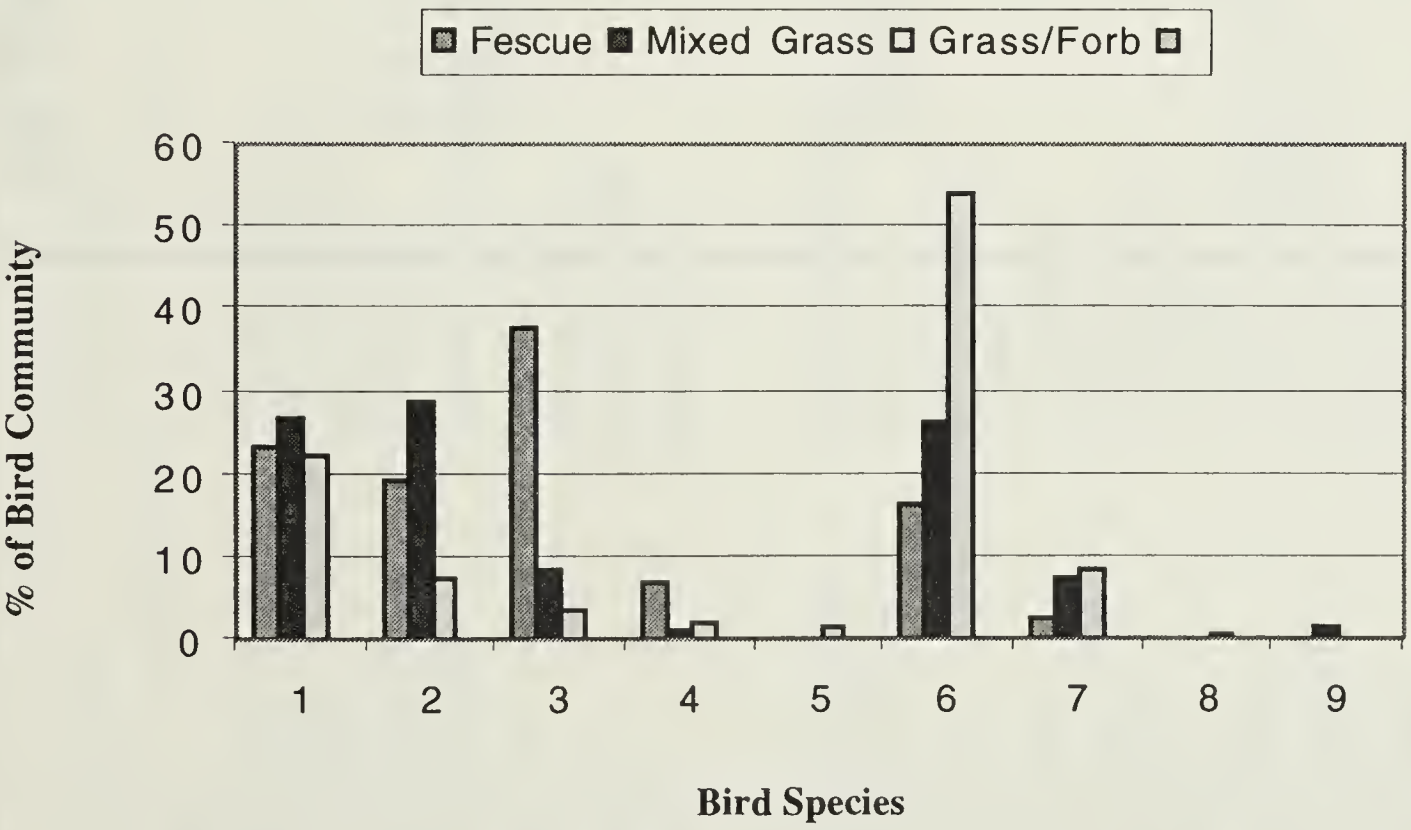
Bird species	Grassland habitat type								
	Fescue			Mixed grasses			Grass/forb		
	r	N[a]	P	r	N[a]	P	r	N[a]	P
Bobolink	0.47	15	<0.10	0.77	9	<0.01*	0.47	16	<0.10
Eastern meadowlark	0.65	14	<0.01*	0.61	9	<0.10	-0.19	15	>0.50
Savannah sparrow	0.80	13	<0.001*	-0.13	4	>0.50	-0.40	7	>0.50
Grasshopper sparrow	0.79	8	<0.01*	-	-	-	-0.83	5	>0.50
Red-winged blackbird	0.17	15	>0.50	0.77	8	<0.02	0.88	16	<0.001*

[a] N = number of grassland fields in which the bird species occurred, combined for both years. For example, of the 8 fescue fields, 5 mixed grasses fields, and 8 grass/forb fields studied during 1986 and 1987, bobolinks were present in all 8 grass/forb fields both years, for N = 16 observations.

* Significant at P=0.05 (t-test).

Figure 1. Frequency of occurrence of 9 bird species in 3 grassland habitat types in northern Illinois, 1986-1987. 1=Bobolink, 2=Eastern Meadowlark, 3=Savannah Sparrow, 4=Grasshopper Sparrow, 5=Dickcissel, 6=Red-winged Blackbird, 7=Song Sparrow, 8=Henslow's Sparrow, and 9=Field Sparrow.

Figure 2. Percentage of the bird community represented by 9 bird species in 3 grassland habitat types in northern Illinois, 1986-1987. 1=Bobolink, 2=Eastern Meadowlark, 3=Savannah Sparrow, 4=Grasshopper Sparrow, 5=Dickcissel, 6=Red-winged Blackbird, 7=Song Sparrow, 8=Henslow's Sparrow, and 9=Field Sparrow.



Appendix I. Field size and length, year of planting, and area of 21 transects within 3 habitat types in northern Illinois, 1986 and 1987.

Field area (ha)	Field length (m)	Year planted	Transect area (ha)
Fescue			
8.9	411	1971/1972	5.1
18.2	594	1979/1983	7.3
20.6	502	1979/1983	6.2
35.2	548	1979	6.7
40.5	937	1978	11.4
52.6	1371	1973	16.7
64.7	807	1979/1982	9.8
87.1	1828	1976	22.3
327.8			85.5
Mixed grasses			
8.9	396	1974	4.8
13.6	457	1974	5.5
18.2	411	1974	5.1
28.3	1005	1974	12.2
40.5	1096	1974	13.4
109.5			41.0
Grass/forb			
8.9	426	1974	5.2
14.5	396	1973	4.8
22.2	579	1971	7.1
27.9	594	1983	7.2
44.5	670	1983	8.2
52.6	777	1971/1972	9.5
64.7	807	1978/1983	9.8
97.1	1035	1978/1982	14.5
332.4			66.3

Appendix II. Plant species occurring within fescue(1), mixed grasses(2), and grass/forb(3) habitat types in northern Illinois, 1986-87.

Common name	Scientific name	Habitat type
Grasses		
Meadow fescue	*Festuca elatior*	1,2,3
Orchard grass	*Dactylis glomerata*	1,2,3
Smooth brome	*Bromus inermis*	1,2,3
Kentucky bluegrass	*Poa pratensis*	1,2,3
Reed canary grass	*Phalaris arundinacea*	1,2,3
Redtop	*Agrostis alba*	2,3
Quackgrass	*Agropyron repens*	1,2,3
Timothy	*Phleum pratense*	1,2,3
Foxtails	*Setaria* spp.	1, 3
Forbs		
Yellow sweet clover	*Melilotus officinalis*	1,2,3
White sweet clover	*M. alba*	1,2,3
Red clover	*Trifolium pratense*	1,2,3
White clover	*T. repens*	1,2,3
Alsike clover	*T. hybridium*	1,2,3
Yellow hop clover	*T. agrarium*	1,2,3
Canada thistle	*Cirsium arvense*	1,2,3
Bull thistle	*C. vulgare*	1, 3
Nodding thistle	*Carduus nutens*	3
Common ragweed	*Ambrosia artemisiifolia*	1,2,3
Giant ragweed	*A. trifida*	3
Field bindweed	*Convolvulus arvensis*	1,2,3
Horse nettle	*Solanum carolinense*	1, 3
Bittersweet nightshade	*S. dulcamara*	1,2,3
Wild parsnip	*Pastinaca sativa*	1
Dogbane	*Apocynum medium*	1, 3
Curled dock	*Rumex crispus*	1,2,3
Common burdoch	*Arctium minus*	1, 3
Wild lettuce	*Lactuca canadensis*	1,2,3
Evening primrose	*Oenothera biennis*	1,2,3
Common plantain	*Plantago major*	2
Goldenrods	*Solidago* spp.	1,2,3
Wild strawberry	*Fragaria virginiana*	2
Cattail	*Typha latifolia*	1,2
Queen-Anne's lace	*Daucus carota*	1,2,3
Daisy fleabane	*Erigeron annuus*	1,2,3
Wild bergamot	*Monarda fistulosa*	1,2
Gray-headed coneflower	*Ratibida pinnate*	1
Peppermint	*Mentha piperata*	1, 3
Velvetleaf	*Abutilon theophrasti*	1
Yarrow	*Achillia millefolium*	1, 3
Cinquefoil	*Potentilla* spp.	1,2,3
Heal-all	*Prunella vulgaris*	1
Common mullein	*Verbascum thapsus*	1, 3
Moth mullein	*V. blattaria*	3

Appendix II. continued

Common name	Scientific name	Habitat type	Common name	Scientific name	Habitat type
Hedge bindweed	*C. sepium*	1,2,3	Dandelion	*Taraxecum officinale*	1,2,3
Common sow thistle	*Sonchus oleroceus*	1,2,3	Smartweed	*Polygonum* spp.	1,2,3
Spiny-leaved sow thistle	*S. asper*	1			
Yellow wood sorrel	*Oxalis europea*	1,2	Shrubs and trees		
Day lily	*Nemerocallis fulva*	2	Raspberry	*Rubus* spp.	1,2,3
Virginia creeper	*Parthenocissus quinquefolia*	2	Blackberry	*R. allegheniensis*	2
Common milkweed	*Asclepia syrica*	1,2,3	Multiflora rose	*Rosa multiflora*	1,2,3
Whorled milkweed	*A. verticillata*	3	Pasture rose	*R. carolina*	1
Yellow goats beard	*Tragopogan pratensis*	2,3	Wild grape	*Vitus* spp.	1,2,3
Chickory	*Cichorium intybus*	2,3	Boxelder	*Acer negundo*	1,2,3
Ox-eye daisy	*Chrysanthemum leucanthemum*	1,2	Silver maple	*A. saccarinu*m	3
Lamb's quarters	*Chenopodium alba*	1,2,3	Willow	*Salix* spp.	1, 3
White vervain	*Verbena urticifolia*	2,3	Eastern cottonwood	*Populus deltoides*	2,3
Blue vervain	*V. hastata*	2			
Bush clover	*Lezpedeza* spp.	3			

Appendix III. Non-grassland birds seen or heard[a] during bird surveys in 3 grassland habitat types in northern Illinois, 1986 and 1987.

Bird species	Fescue	Mixed grasses	Grass/forb
Eastern kingbird (*Tyrannus tyrannus*)	+(+)	+(+)	+(+)
Barn swallow (*Hirundo rustica*)	+(+)	+(+)	+(+)
Tree swallow (*Irodoprocne bicolor*)	+(+)	+(+)	+(+)
Red-tailed hawk (*Buteo jamaicensis*)	+(+)	+(+)	-(+)
Northern harrier (*Circus cyaneus*)	-(+)	-(-)	-(-)
Common crow (*Corvus brachyrhynchos*)	+(+)	+(+)	+(+)
Common grackle (*Quiscalus quiscula*)	+(+)	+(+)	-(+)
Yellow warbler (*Dendroica petechia*)	-(-)	-(-)	-(+)
Mourning dove (*Zenaidura macroura*)	+(+)	+(+)	-(+)
American kestrel (*Falco sparverius*)	+(+)	+(-)	-(+)
American robin (*Turdus migratorius*)	+(+)	+(+)	+(+)
Brown-headed cowbird (*Molothrus ater*)	+(-)	-(-)	-(+)
American goldfinch (*Spinus tristis*)	+(+)	+(+)	-(+)
Common yellowthroat (*Geothlypis trichas*)	-(+)	-(+)	+(+)
European starling (*Sturnus vulgaris*)	-(+)	+(+)	+(+)
American killdeer (*Charadrius vociferus*)	-(+)	+(+)	-(-)
Northern flicker (*Colaptes auratus*)	-(-)	+(+)	+(+)
Brown thrasher (*Toxostoma rufum*)	-(+)	-(-)	+(+)
Sedge wren (*Cistothorus platensis*)	-(+)	-(-)	+(+)
Chimney swift (*Chaetura pelagica*)	-(+)	-(+)	-(-)
Gray catbird (*Durnetella carolinensis*)	-(+)	-(-)	-(-)
Ring-necked pheasant (*Phasianus colchicus*)	+(+)	+(+)	+(+)

[a] + = presence, - = absence. Data from 1987 in parentheses.

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 133-135

received 11/21/97
accepted 9/7/98

New State Record Lengths and Associated Natural History Notes for some Illinois Snakes

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ABSTRACT

Record length snakes of four species and associated natural history information are reported from Carroll and Whiteside Counties, Illinois. Three of the snakes (*Heterodon nasicus nasicus, Pituophis melanoleucus sayi,* and *Thamnophis sirtalis sirtalis*) were captured in sand prairie habitat and the other (*Elaphe vulpina vulpina*) on a muddy bank of the Mississippi River. A large brood from the *T. s. sirtalis* (83 neonates) and food items for *H. n. nasicus* are also reported.

INTRODUCTION

Although Boundy (1995) recently reviewed records for maximum lengths of North American snakes, the most recent record of maximum lengths of Illinois snakes was published over thirty-five years ago (Smith, 1961). Herein we report large individuals of four species of snakes collected in Carroll and Whiteside Counties, Illinois with total lengths longer than those cited by Smith (1961). Also reported are June feeding habits for *H. n. nasicus* in sand prairie habitat and a record size brood from the record length *T. s. sirtalis*.

METHODS AND MATERIALS

All snakes were captured by hand during June, 1997, and were subsequently marked, measured, and released at the capture site. For each snake, total length (TL) was measured in millimeters from tip of snout to tip of tail. Locations for three of the snakes were determined with a Global Positioning System. Photographs were vouchered with the Illinois Natural History Survey for the *Elaphe vulpina vulpina* (INHS 1998-1), *Pituophis melanoleucus sayi* (INHS 1998-2), and *Thamnophis sirtalis sirtalis* (INHS 1998-3).

RESULTS AND DISCUSSION

The large western fox snake (*Elaphe vulpina vulpina)* (TL=1600 mm) was captured on 27 June 1997 at 1700 hr hiding in a hollow piece of driftwood at the Thomson Causeway Recreation Area (Carroll Co.). We recaptured this female snake 3 d later in the rotting root of a tree 25 m north of the first capture on the same bank. The record length for the species *E. vulpina* listed in Conant and Collins (1991) is 1791 mm, but neither the locality nor the subspecific designation is reported for this snake. The largest Illinois specimen previously reported for a fox snake was 1297 mm (Smith, 1961).

The bullsnake (*Pituophis melanoleucus sayi)* was captured on 2 June 1997 while basking in a small patch of prickly-pear cactus at the Thomson-Fulton Sand Prairie in Whiteside Co. (41° 55' 8.0" N, 90° 6' 0.9" W). With a TL of 1937 mm, this male snake was larger than the one reported by Smith (1961) with a TL of 1880 mm.

A female plains hognose snake (*Heterodon nasicus nasicus*) (TL=705 mm) was caught on 9 June 1997 at the Thomson-Fulton Sand Prairie in Whiteside Co. (41° 55' 9.8" N, 90° 6' 58.6" W). The largest Illinois specimen previously reported was 593 mm (Smith, 1961).

Predation on turtle eggs by western hognose snakes has been reported for Whiteside Co. (Barten, 1980), Kansas and Nebraska (Platt, 1969), and western Nebraska (Iverson, 1990). On two occasions, 8 June and 11 June 1997, we found hognose snakes with their heads inside *Chrysemys picta* nests consuming eggs. The snakes had eaten 4 and 1 egg(s), respectively, before being collected. A total of 9 snakes was found to have eaten eggs in 1997 (mean number of eggs eaten per snake=4.11; SD=2.23). Overall, 9 of 52 snakes (17.3%) collected in June 1997 had consumed eggs. Platt (1969) reported a maximum of 11.1% or 2 of 18 snakes that he examined contained turtle eggs.

We also observed predation by hognose snakes on six-lined racerunners (*Cnemidophorus sexlineatus*). Platt (1969) reported racerunners as food items for as many as 22.2% (12 of 54 snakes) of western hognose snakes he examined. On 24 June 1996, a hognose snake was found under a board struggling with a racerunner, and on 4 June 1997, a hognose was collected with a partially swallowed racerunner in its mouth. The snake was collected and finished ingesting the lizard while in captivity. The frequencies of 6.7% (1 of 15 snakes) for 1996 and 1.9% (1 of 52 snakes) for 1997 are considerably less than those reported by Platt (1969).

The eastern garter snake (*Thamnophis siratalis sirtalis)* (TL=1066) individual was caught on 4 June 1997 at the Thomson-Fulton Sand Prairie in Whiteside Co. (41° 55' 17.3" N, 90° 6' 54.4" W). This snake was slightly larger than the largest Illinois specimen reported by Smith (1961, TL=1044). The female gave birth to a litter of 83 viable neonates while in captivity, which is 30 more than the largest Illinois litter size of 53 (Cagle, 1942) reported in Smith (1961). In addition, it may be the largest litter of viable neonates documented; only Martof (1954) has reported a larger litter size of 85, but 7 were dead at birth. Data collected from the neonates of this large litter include mass (mean=1.59 g; SD=0.106 g), SVL (mean=145.61 mm; SD=4.45 mm), and TL (mean=191.18 mm; SD=6.08 mm).

ACKNOWLEDGEMENTS

Snakes were collected under Illinois Department of Natural Resources permit numbers 96-7S and NH-97.0044, U.S. Fish and Wildlife Service Permit Number 97011, and supported in part by NSF grant DEB-9629529 to Fred Janzen and NBS contract 8205060121 from the Northern Prairie Wildlife Research Center to Fred Janzen and David Weisrock. JJK was supported by fellowships from the Department of Zoology & Genetics and the Graduate College at Iowa State University and a Fung Excellence Award, LJH was supported by NSF REU grant DEB-9741936 to Fred Janzen, and DAW was supported by a grant from the Chicago Herpetological Society and a Department of Zoology & Genetics Summer Internship. We thank Dean Thompson of the National Resources Institute for the generous loan of their GPS equipment, Fred Janzen, John Tucker, and two anonymous reviewers for commenting on the manuscript, Edmund D. Brodie, Jr. for data on the neonates of the garter snake litter, and the turtle camp crew from 1997: Nirvana Filoramo, Paul Magwene, Carrie Milne, Nick Notis, and David Weisrock.

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 137-145

received 6/22/98
accepted 10/14/98

Distributional and Ecological Notes on some of Illinois' Burrowing Crayfishes

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ABSTRACT

Recent field work has shown the prairie or grassland crayfish, *Procambarus gracilis*, to occur commonly in forested regions of northeastern Illinois and the digger crayfish, *Fallicambarus fodiens*, to persist in similar habitats of that same region. In addition, a search of major museum holdings revealed a new drainage record for *F. fodiens* in Illinois. Both results demonstrate that there is still much to learn about Illinois decapod crustaceans and highlight the need for continued research.

INTRODUCTION

Based primarily on the amount of time individuals spend below ground, burrowing crayfishes have been assigned to one of three categories: primary, secondary, and tertiary burrowers (Hobbs 1989). Primary burrowers usually spend the majority of their life cycles in burrows, emerging only briefly to forage for food or to mate. Females of most primary burrowers will migrate to standing water habitats for a limited time period, usually in the spring, to disperse their young. Because of these behaviors, primary burrowers are difficult to collect and often are underrepresented in faunal survey collections. Likewise, ecological information on primary burrowers is often rudimentary.

Three primary burrowing crayfish species are known to occur in Illinois (Hobbs 1989; Page 1985): *Cambarus diogenes* Girard 1852, a common inhabitant of the central United

States from northern Minnesota to the gulf coast and the Atlantic Piedmont and Coastal Plain (Jezerinac 1993); *Fallicambarus fodiens* (Cottle 1863), known from the Great Lakes (except Lake Superior) to the gulf coast and the central Atlantic Piedmont and Coastal Plain (Hobbs and Robison 1989); and *Procambarus gracilis* (Bundy 1876), known from western Indiana and southeastern Wisconsin to southeastern Nebraska, eastern Kansas and Oklahoma, and northeastern Texas (Page 1985). We report here on ecological observations of *Procambarus gracilis*, new distributional records for *Fallicambarus fodiens* obtained during general crayfish surveys conducted from 1996 to 1998 in northeastern Illinois, and on a new Illinois *F. fodiens* record from museum holdings.

MATERIALS AND METHODS

In an effort to document the crayfish fauna of properties owned by the Cook County Forest Preserve District, general sampling of aquatic and semi-aquatic habitats was conducted from July 1996 to May 1998. Additional sites in adjoining DuPage, Lake, and Will counties were sampled from May 1997 to June 1998. A total of 21 sites was sampled during the above time frame. Crayfishes were collected using several methods: hand-held dip nets, 1.5 m x 3.0 m minnow seine, and unbaited wire mesh minnow traps. Voucher specimens were deposited in the Illinois Natural History Survey Crustacean Collection. At Swallow Cliff Forest Preserve, located approximately 2.5 km NW of the town of Palos Park (T37N, R12E, Sec. 28), Cook Co., Illinois, 6 minnow traps were submerged in a vernal pond from 1 May to 1 July 1997; traps were checked every 48 hours. Crayfishes collected in the traps were identified, sexed, and returned to the water. The Crustacean Collection of the United States National Museum, Smithsonian Institution (USNM), also was searched for additional Illinois *F. fodiens* records.

RESULTS

During 1996 and 1997 we frequently collected *Procambarus gracilis*, commonly known as the prairie (Williams et al. 1989) or grassland (Pflieger 1996) crayfish, from shallow vernal ponds located in closed-canopy mesic hardwood forests (Fig. 1, Appendix 1). Forest soils of the Morley silt loam and Blount silt loam series were the dominate types found at these sites (Soil Conservation Service 1970, Soil Conservation Service 1979, Soil Conservation Service 1980).

On 28 April 1997 a population of *P. gracilis* was discovered at the Beaubien Woods/Flatwood Lake Forest Preserve in southern Cook County. The crayfishes were collected around the edges of a 15 acre human-made fishing lake. This small (289 acre) highly disturbed forest preserve is located in one of the most urbanized and industrially developed regions in the Chicago metropolitan area. It is bordered on the south by the Little Calumet River, on the west by the community of Altgeld Gardens, and on the north and east by Interstate 94 and municipal refuse land fills. Very little native vegetation remains in the Forest Preserve.

The digger crayfish, *Fallicambarus fodiens*, was collected from 11 previously unrecorded northeastern Illinois locations between 1996 and 1998 (Fig. 2, Appendix 2). Our sampling also reconfirmed the presence of the species at one historical site (Tinley Woods Forest Preserve, Cook Co.). At all of these locations, the species was collected from ver-

nal woodland ponds (Fig. 1) using dip nets and/or unbaited wire mesh minnow traps. Water depths in these ponds ranged from 0.1 to 0.4 m. The species also was collected from 2 locations in the upper Embarras River drainage of southeastern Illinois (Appendix 2, Fig. 2). In addition, examination of material in the USNM Crustacean Collection revealed the first record for *F. fodiens* from the Kaskaskia River drainage in southwestern Illinois (Fig. 2, Appendix 2).

Since individuals of *F. fodiens* collected in minnow traps at the Swallow Cliff Forest Preserve were returned to the pond after being identified, it is difficult to estimate population size. However, on several occasions 15 individuals were trapped in a 48 hr. period. Trapping efforts at two other sites, MacArthur Woods Nature Preserve and Edward L. Ryerson Nature Preserve, produced 20 and 17 individuals, respectively, in a two-week period. At both of these preserves, approximately 5 to 10% of the suitable habitat was sampled.

DISCUSSION

Page (1985) listed *F. fodiens* as occurring historically in the Ohio, Big Muddy, Sangamon, Illinois, and Lake Michigan drainages of Illinois. During his statewide survey of Illinois decapods, Page (1985) did not collect *F. fodiens* from the northern half of the state. This, most likely, precipitated his hypothesis that the species had experienced a range reduction in northern and central Illinois. Our recent collections of *F. fodiens* indicate that in northeastern Illinois, the species occurs in the Kankakee River drainage and still occurs commonly in the Des Plaines River drainage. In this region, the species was always encountered in shallow vernal ponds within closed-canopy mesic hardwood forests (Fig. 1). Vegetation in these ponds are dominated by sedges of the genus *Carex*. In extremely urbanized northeastern Illinois, this type of habitat is found almost entirely in state- or county-owned Forest Preserves and Nature Preserves. The presence of *F. fodiens* in these preserves reinforces the need for the protection of unique habitat types in regions experiencing rapid urban growth if native biodiversity is to be preserved. A newly discovered USNM record from the Kaskaskia river drainage, collected in 1972, and two records from the upper Embarras River drainage (Fig. 2) collected in 1997 and deposited in the INHS Crustacean Collection indicate that *F. fodiens* is more widespread in the southern one-third of Illinois than previously known.

Using soil as the indicator for past plant communities (Buol et al. 1989), sites at which *P. gracilis* were collected were likely forested in pre-settlement times. Previous authors (Page 1985, Pflieger 1996, Downing 1924, and Creaser 1932) suggest that *P. gracilis* may be restricted to grassland (or former grassland) and prairie regions throughout its range. In southeastern Wisconsin, the presumed range of *P. gracilis* occurs in areas that were once dominated by oak savanna, prairie, and sedge meadow (Hobbs and Rewolinski 1985). Our results indicate that, in northeastern Illinois, *P. gracilis* also occurs commonly in habitats that have historically been and continue to be densely forested and suggest that the species has a wider tolerance of habitat conditions than previously thought. *Procambarus gracilis* has now been recorded from several habitat types including prairies or former prairies, roadside ditches, wet meadows, and vernal ponds in mesic forests. The inability of crayfishes to tolerate habitat degradation and low water quality has been suggested (World Wildlife Fund 1990), as has their use as indicators of environmental

quality (The Nature Conservancy 1996). The Beaubien Woods/Flatwood Lake Forest Preserve population demonstrates the ability of *P. gracilis* to persist within disturbed habitats, which in turn may preclude its use as an indicator species. Further research is needed to determine whether other burrowing crayfishes show a similar resiliency to disturbance.

Recently, Taylor et al. (1996) highlighted the depauperate state of North American crayfish biogeographical literature and emphasized the need for current distributional and biological data. The above results provide new information for two burrowing midwestern species and demonstrate that there is still much to gain from future faunal surveys and field observations of crayfishes in areas that have been well sampled.

ACKNOWLEDGMENTS

We thank the Illinois Nature Preserves Commission and the Forest Preserve Districts of DuPage and Lake counties for providing the necessary permits to complete this work. We also thank L. Machung for assistance in determining soil types and R. Szafoni and R. Singer for depositing their collections in the INHS Crustacean Collection. K. Reed graciously provided records from USNM and L. Page and M. Sabaj reviewed an earlier version of this manuscript. Partial funding for travel expenses was provided by the Illinois Department of Transportation.

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Appendix 1. Forested sites at which *Procambarus gracilis* was collected during 1996 and 1997. Museum catalog numbers are indicated parenthetically, dates are those on which voucher specimens were collected.

Cook County

1. Ned Brown Forest Preserve, 3.2 km S Rolling Meadows; T41N, R11E, Sec. 17, SE1/4. 17 April 1996 (INHS 5673).
2. Ned Brown Forest Preserve, 1.6 km SE jct. I-90 and I-290; T41N, R11E, Sec. 17, NW1/4. 2 April 1997 (INHS 5932).
3. Deer Grove Forest Preserve, 4.0 km E Barrington; T42N, R10E, Sec. 4, NW1/4. 2 April 1997 (INHS 5942).
4. Deer Grove Forest Preserve, 4.0 km E Barrington; T42N, R10E, Sec. 4, SE1/4. 30 May 1997 (INHS 6001).
5. Swallow Cliff Forest Preserve, 1.2 km SW jct. U.S. Hwy. 45 and IL Rt. 83; T37N, R12E, Sec. 28, NE1/4. 31 March 1997 (INHS 5953), 28 May 1997 (INHS 6008).
6. Steger Woods Forest Preserve, just N of Sauk Trail Ave.; T35N, R14E, Sec. 31, NE1/4. 3 June 1997 (INHS 5999).
7. Somme Woods East Forest Preserve, 0.5 km N Northbrook; T42N, R12E, Sec. 3, SW1/4. 2 June 1997 (INHS 6000).

Lake County

8. Edward L. Ryerson Nature Preserve, 1.6 km S Lincolnshire; T43N, R11E, Sec. 26, NE1/4. 28 May 1997 (INHS 6011)

Will County

9. Goodenow Grove Forest Preserve, 5.6 km E Crete; T34N, R14E, Sec. 13, NE1/4. 4 June 1997 (INHS 6002).

Appendix 2. Locations for new Illinois records of *Fallicambarus fodiens*. Drainage basin and Museum catalog numbers are indicated parenthetically, dates are those on which voucher specimens were collected. dr. = drainage.

Cook County

1. Plum Creek at Plum Creek Forest Preserve (Lake Michigan dr.); T35N, R15E, Sec. 32. 2 April 1997 (INHS 5718).
2. Vernal pond at Swallow Cliff Forest Preserve, 1.2 km SW jct. U.S. Hwy. 45 and IL Rt. 83 (Des Plaines R. dr.); T37N, R12E, Sec. 28, NE1/4. 12 May 1997 (INHS 5931) and 23 May 1997 (INHS 6003).
3. Vernal pond at Ned Brown Forest Preserve, 3.2 km S Rolling Meadows (Des Plaines R. dr.); T41N, R11E, Sec. 17, SE1/4. 29 April 1998 (INHS 6658).

Crawford County

4. Maple Creek 5 km WSW Annapolis (Embarras R. dr.); T8N, R13W, sec. 16, SW. 18 May 1997 (INHS 5870).

Cumberland County

5. Field 5 km NNE Greenup (Embarras R. dr.); T10N, R9E, sec. 24, SE. 14 April 1997 (INHS 5980).

DuPage County

6. Vernal pond 4.0 km S Willowbrook (Des Plaines R. dr.); T37N, R11E, Sec. 11, NW1/4. 28 May 1997 (INHS 6013).
7. Vernal pond at Wood Dale Grove Forest Preserve, 0.8 km S Wood Dale (Des Plaines R. dr.); T40N, R11E, Sec. 22, NW1/4. 8 June 1998 (INHS 6709).

Lake County

8. Vernal pond at Edward L. Ryerson Nature Preserve, 1.6 km S Lincolnshire (Des Plaines R. dr.); T43N, R11E, Sec. 26, NE1/4. 2 April 1998 (INHS 6653)
9. Vernal pond at MacArthur Woods Nature Preserve, 1.6 km SE Libertyville (Des Plaines R. dr.); T44N, R11E, Sec. 34, SE1/4. 15 April 1998 (INHS 6655)
10. Vernal pond at Elm Road Forest Preserve, 1.6 km S Mettawa (Des Plaines R. dr.); T43N, R11E, Sec. 11, SW1/4. 15 April 1998 (INHS 6652)

Monroe County

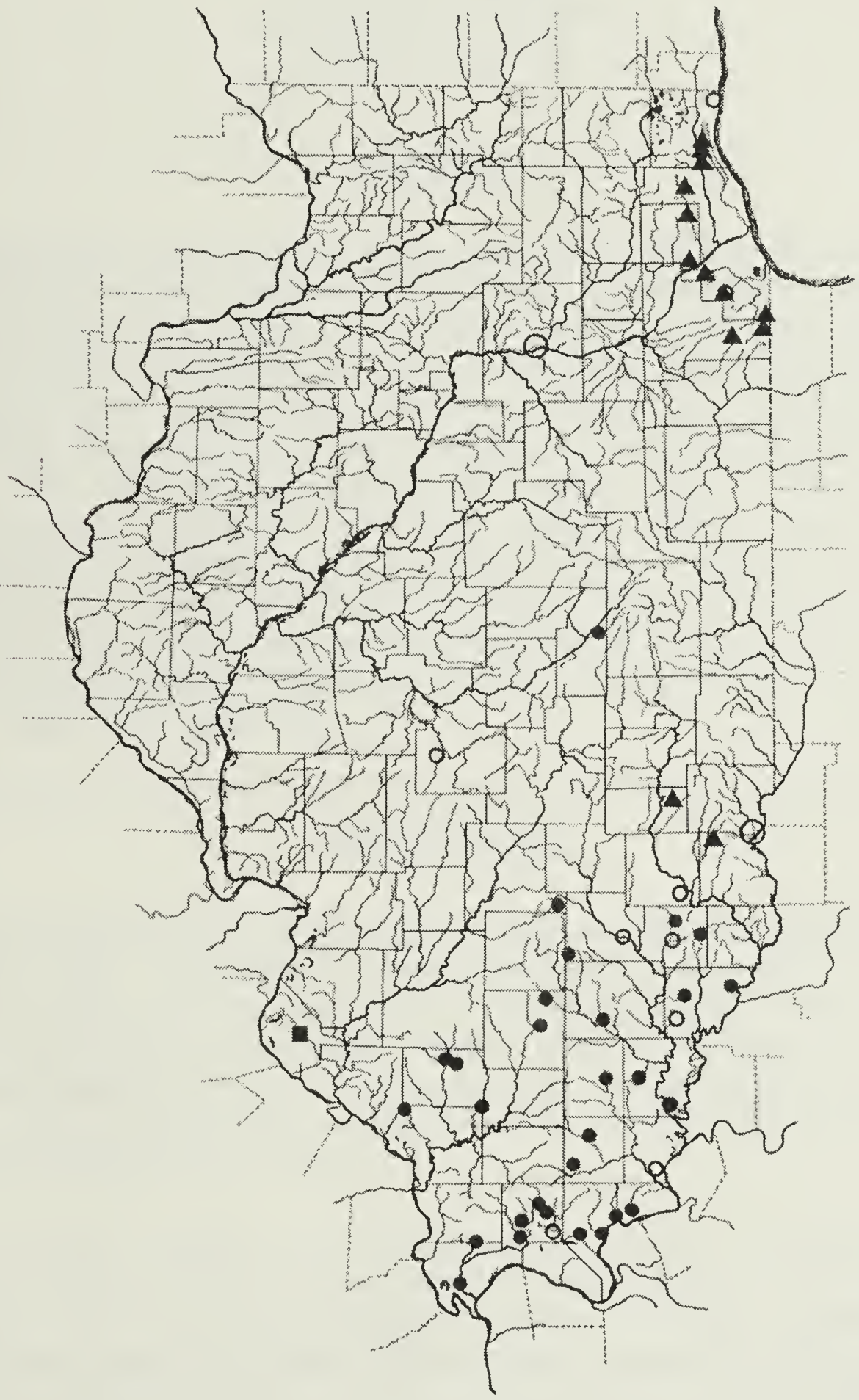
11. Roadside ditch 3.2 km E Burksville (Kaskaskia R. dr.); T3S, R9W, Sec. 20, NW1/4. 1972 (USNM 133487).

Will County

12. Vernal pond at Raccoon Grove Forest Preserve, 2.8 km SSW Monee (Kankakee R. dr.); T34N, R13E, Sec. 32, NE1/4. (INHS 6005).
13. Vernal pond along Old Post Rd., 2.4 km ESE Crete (Lake Michigan dr.); T34N, R15E, Sec. 7, SW1/4. (INHS 6706).

Figure 1. An example of the habitat in which *Fallicambarus fodiens* and *Procambarus gracilis* were frequently collected during the present study: a vernal pond within closed-canopy mesic hardwood forest.

Figure 2. Distribution of *Fallicambarus fodiens* in Illinois. Open (large = 1890-1901, small = 1950-1955 collections) and closed circles (1972-1982 collections) are localities reported by Page (1985); triangles denote localities at which the species was collected during the present study; square denotes USNM record for Kaskaskia River drainage.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 1 and 2, pp. 147-161

received 4/17/98
accepted 8/5/98

Herpetofaunal Changes in McDonough County, Illinois

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ABSTRACT

Herpetological changes and present status are described for McDonough County, Illinois, located on the flat uplands between the Mississippi and Illinois rivers. This primarily agricultural county was formerly mostly prairie and is poorly represented in large museum collections. The status of 55 species is reported. Four salamanders and ten frogs are native to the county, of which *Hemidactylium scutatum* and *Rana utricularia* are noteworthy. One introduction (*Rana clamitans*) is noted here, and two were reported previously. Five native turtles, one lizard, and 15 snakes remain. Noteworthy reptiles include *Carphophis, Diadophis* (two races), *Virginia valeriae, Thamnophis radix, Nerodia erythrogaster* and *Agkistrodon contortrix.* Ten of the present 35 native herptiles were not shown for McDonough County by Smith (1961), and 12 species that he did indicate appear to be absent now. The difficulties of reptile survival and conservation are discussed. Local amphibian environmental factors are also noted, and recommendations are made for preserving herptile fauna.

INTRODUCTION

Massive human habitat destruction is generally realized, but is still shocking when pictured (Curtis, 1956). Biodiversity loss from cumulative gradual environmental degradation also proceeds unnoticed. Larger animals leave early from human predation or because the ecosystems will no longer support them (Hoffmeister, 1989), but even smaller vertebrates like herptiles fade away. In a classic paper on the effect of urbanization in the midwest (Indianapolis area) Minton (1968) describes herptile losses as breeding places and other resources disappear.

This paper details a similar process for McDonough County, in west-central Illinois, where environmental alteration has mainly been through agriculture. There is only one large (central) area of growing urbanization (Macomb). Public semi-protected areas include one state park (Argyle Lake) with surrounding Department of Natural Resources land, one city park (Spring Lake), and some property owned by Western Illinois University. There are no county, state, or federal nature preserves, game preserves, or conservation areas except Ferster Wood (30 acres). Possibilities for preserving even large samples of prairie, woodland, and wetland ecosystems are limited because of Illinois habitat transformations (illustrated by Graber and Graber, 1963). However, sample populations of plants or smaller animals can be maintained or even increased by private action, thus

reducing species losses, if not population decreases. Some habitat is preserved on steeper slopes near waterways, and some modified habitat exists along streams, railroads, highways, and even fence rows and "odd corners". Habitat can be improved or created (Thurow 1994a, 1994b, 1997, and articles by others in the Natural Areas Journal or Restoration and Management Notes).

McDonough County is square, 24 miles (38.6 km) per side (Fig. 1). It lies in the Prairie Peninsula of Transeau (1935), and is centrally located on the relatively flat upland between the Mississippi and Illinois rivers. The county is crossed by the LaMoine River and its east fork, and a soil map shows where the forest and prairie once occurred (Bushue, et al., 1970). Additional maps are given by Presley (1994). The forest is now fragmented (Hoffmeister, 1989, Presley, 1994), and the prairie largely converted to crop fields. Figure 1 is based on 1963 aerial photographs. A newer source (Department of Natural Resources, 1996) lists 71.5% cropland, 14.3% grassland, 10.4% forest/woodland, and 3.7% wetland and other for McDonough County. The county is covered by Illinoian glacial till and loess, but there are scattered rock outcrops. The average (1951-1996) annual temperature is 51.8° F and the average precipitation is 37.4 inches (personal communication from Dr. D. Wise, Western Illinois University Climatic Station).

MATERIALS AND METHODS

Literature records, personal communications from local people, and 30 years of field work were used for information. I believe county-wide observations over a longer period give more meaningful abundance indicators than generalizations from limited quantitative sampling. In other words, the number of locations does not necessarily indicate the number of animals.

Museum collections were not surveyed extensively, except for the Western Illinois University (WIU) collection and my collection (GRT). Other parts of Illinois had more herptile collecting (Smith, 1961), and there are few McDonough County specimens in larger collections. Curators informed me that there are none at the Chicago Academy of Science, the Field Museum of Natural History, Eastern Illinois University, Illinois State University, Northern Illinois University, or Southern Illinois University at Edwardsville. I examined Knox College specimens, and found none from McDonough County. In early 1997 the Illinois Natural History Survey (INHS) had 25 McDonough County specimens (11 species). Specific population localities are mainly omitted in the present paper, for their protection. The herptile species are described under three categories: 1) those which are widespread in the county, though in diminishing numbers; 2) those which are uncommon to rare, or with restricted distributions; and 3) those which are very rare or extirpated, or whose survival is unknown. The latter two categories include three new species translocated into McDonough County. The current status is discussed for 55 herptiles indicated to be in the general area (Conant and Collins, 1991, whose nomenclature I follow). I have seen all 55 entities alive as well as preserved, except possibly *Tropidoclonion*. I have identified living specimens from McDonough County for all 35 native herptiles presently judged to be extant, except *Sternotherus* and *Nerodia erythrogaster*.

RESULTS (Species Accounts)

Widespread Species - Amphibians

1) *Ambystoma texanum* - is common in less disturbed areas near water. Adults do not require high quality woodlands, have been found in pasture, yard, and garden burrows, and can breed in small temporary ponds like roadside ditches.

2) *Bufo americanus* - was once abundant, but declined after the 1988-1989 drought (see Owen and Chiras, 1990, p. 129, about the drought). This toad is recovering, as evidenced by more sightings and more choruses. It can utilize small impoundments and even backyard artificial pools. Tadpoles survive with large predatory fish by occupying very shallow pond margins, or spaces surrounded by aquatic vegetation.

3) *Acris crepitans* - was once the most abundant frog in the county, but declined even more after the 1988 drought, perhaps because it breeds later in the season. *Acris* is also recovering, and can again be found along stream and pond margins through most of the county in 1996 and 1997, though not in its former abundance. I examined some waters on my farm every year since 1970. Older specimens include WIU 88-94 and 306-317. More recent specimens include WIU 643 and INHS 12751, 12760, and 12766.

4) *Hyla versicolor* - can be heard calling in most areas with trees. It also declined after the 1988 drought, and is recovering, with large choruses and many eggs in 1997.

5) *Pseudacris crucifer* - calls abundantly at a few areas, and sporadically in others. It is more numerous along the wooded bluffs of the LaMoine River, particularly downstream and west of Macomb. On my farm away from the river and northeast of Macomb, *P. crucifer* was quite rare. Local calling did increase some in 1994-1997, either from immigration following forest maturation or from augmentation with some local frogs and tadpoles.

6) *Pseudacris triseriata* - is probably the most abundant frog in the county at present, based on the number of choruses, though it is secretive and not often seen away from the breeding ponds. This frog can breed in roadside ditches, tire ruts, and other small temporary waters near grassy areas.

7) *Rana blairi* - is widespread and relatively common in its remaining habitat. It can breed in smaller and more temporary waters than the bullfrog, and may be found in damp grass some distance from water.

8) *Rana catesbeiana* - is common in ponds and along streams and rivers. It can breed in nearly any mostly permanent pond above a certain size, such as the Bardolph municipal sewage lagoon and a WIU campus golf course pond. Bullfrogs disperse well, and can temporarily occupy puddles or backyard artificial pools.

Widespread Species - Reptiles

9) *Chelydra serpentina* - is a turtle found throughout the county. I have seen it in many streams and ponds, and crossing roads.

10) *Chrysemys picta* - is the most common and widespread turtle in the county. I have seen it more often and at more sites than other turtles. It is found in streams and ponds of about any size, and a hatchling crawled through my backyard over 50 m from a temporary stream.

11) *Trachemys scripta* - is larger and less common than *Chrysemys*, and is not found in the smaller ponds and streams except as juveniles. Some pet store and biological supply house specimens probably were released in Macomb, in addition to the native population.

12) *Thamnophis sirtalis* - is the most common and most widespread snake, based on sightings and road kills, and is the last to disappear in disturbed habitat.

The next five snakes are listed in order of decreasing approximate abundance, based on my sightings over the years.

13) *Storeria dekayi* - is found under cover in grasslands and forest. It is secretive, and not seen often except in much visited population sites. In 1997 they were frequently encountered on my farm.

14) *Nerodia sipedon* - is found near or in water. It can be locally abundant near a food source, such as below dams. When pollution reduced the number of small fish in my farm stream, the number of *N. sipedon* decreased also.

15) *Lampropeltis calligaster* - is a semi-fossorial form that mostly lives in or near grasslands. Highway right-of-ways are important connecting habitat, even though mowing machines and traffic cause fatalities.

16) *Coluber constrictor* - was once fairly common in woods and fields, but it is now declining and mostly found where people go less often. In 25 years I have seen it decrease from fairly common to uncommon on my farm and the immediate neighborhood. Only one was encountered there in 1996 and none in 1997.

17) *Elaphe obsoleta* - is declining because of deforestation and persecution. This semi-arboreal form still occurs with some frequency on wooded banks and bluffs along the LaMoine River and its tributaries, particularly in the southwest quarter of the county. *Elaphe* travels well and occasionally is encountered far from the river, near a barn with rodents, or after flooding. On my farm upriver to the northeast there was one visitor in the 1970s, and a shed skin was left in the attic of my house around 1995.

Uncommon to Rare Species, or Those with Restricted Distribution - Amphibians

18) *Ambystoma tigrinum* - is an increasingly rare salamander (WIU 59), because it requires larger breeding ponds with more food resources. Such ponds are disappearing or becoming unsuitable, mainly because of stocking with predatory fish and disruption by livestock (mostly cattle). The latter increase siltation and pollution, and decrease shore vegetation. The tiger salamander is now extirpated from several ponds where it was formerly reported, or where I had seined larvae. The one pond with reliable sightings is silting in from tractor raised dust.

19) *Necturus maculosus* - has occasionally been taken from the LaMoine River by fishermen over the years, (WIU 248, 617), and presumably breeds in selected riffle and tributary areas. The most recent report was in 1994, a little downstream and outside the county border. So some *Necturus* remain in the river, although silt and pollution have increased.

20) *Bufo woodhousei fowleri* (or *B. fowleri* by Sullivan et al., 1996) - is now rare in the county. It occupies sand areas along major rivers and streams. It is still numerous along the Mississippi and Illinois rivers, less so along the upper Spoon River in adjacent Fulton County, and still less along the upper LaMoine River in McDonough County. I encountered very few individuals from 1966-1996. There is a 1963 (WIU 83) record from Lake Argyle, a 1953 INHS specimen (7179) from the same general area, and a 1967 specimen from downstream (WIU 109). Human disturbance (habitat fragmentation and river siltation) has contributed to decline. I heard one *B. w. fowleri* call from a recently failed (empty) impoundment near my farm in 1983. Since then there have been no calls or sightings in the neighborhood. This species could decline to extirpation in the county.

21) *Hyla chrysoscelis* - is less abundant and widespread than *H. versicolor*. The calls of these two are not always easy to distinguish, particularly if they are not both calling at once. It appears that *H. chrysoscelis* may be uncommon to rare in the county. If *H. chrysoscelis* is totally green when calling (Vogt, 1981) then I have seen both this form and *H. versicolor* on my house.

22) *Rana sylvatica* - was introduced to the county (Thurow, 1994a). This frog is flourishing, although only found on three adjacent farms.

23) *Rana utricularia* (also called *R. sphenocephala*) - has recently been found just south of the county (Thurow and Sliwinski, 1991), and I found a few more recently (1993 on) from the south margin of the county (GRT 3250) and later on my farm northeast of Macomb (GRT 3251). They co-exist with *R. blairi*, and I found them together under rocks along the LaMoine River bank. In 1996 INHS collectors took two specimens northeast of Macomb (INHS 12757-8), one south (INHS 12765), and one to the southeast (INHS 12762). Extensive sampling between 1966-1990 by myself and WIU students previously revealed only *R. blairi*. Possibly *R. utricularia* was missed earlier, but it appears to be expanding its range northward. From my experience in Pike County, *R. blairi* is found more by upland ponds and streams, and *R. utricularia* is more often in river bottoms.

Uncommon to Rare Species, or Those with Restricted Distribution - Reptiles

24) *Apalone spinifera* - a few specimens have been seen or taken from the LaMoine River (I identified some of the latter), and Don Moll trapped specimens from various parts of the river in the early 1970s (personal communication). This species is seen less often than the above three turtles, but may not be rare in the river. I saw one in southwest McDonough County (near Colmar) in 1997. This turtle is common in some Pike County streams and Mississippi River lowland ditches, and in the backwaters along the lower Spoon River in Fulton County.

25) *Sternotherus odoratus* - is a widespread and tolerant species that should occur in McDonough County, but there are no WIU specimens. This species is more difficult to see basking, and is rarly encountered even where I know they occur, as in Pike County. However, Don Moll trapped this form along the LaMoine River, in the early 1970s (personal communication).

26) *Eumeces fasciatus* - is restricted to a few places along the south margin of the county. I identified and released three individuals, and saw others through 1993. This lizard was once more widespread in the south half of the county, as estimated by Smith (1961). Recent strip mining and logging make the lizard's position more rare and precarious.

27) *Carphophis vermis* - is a snake which has spread east to McDonough County from the Mississippi bluffs. It can usually be found for a short period in April. The best of my two known relict populations (WIU 513) was extirpated by overgrazing and erosion. Fortunately I later found two other *Carphophis* colonies in south McDonough County. The snake was once more widespread locally, as evidenced by the discontinuous relict colonies.

28) *Diadophis punctatus* - is a small snake which has mainly spread along the rocky bluffs of the Mississippi and Illinois rivers in west-central Illinois. The race *D. punctatus arnyi* has spread east from the Mississippi to the west margin of McDonough County. One colony followed the bluffs along the west fork of the LaMoine River. A second was introduced accidentally, hauled in among fill rock in railway cars when the first Colmar railroad bridges were built in 1856 and 1879. More may have been added when a later bridge was built nearby in 1955. Railroad personnel confirmed the bridge dates, and the rock fill is the only suitable *Diadophis* habitat in the area. The fill rock and snakes probably came from an old Marblehead quarry I found near the railroad, in Adams County.

In 1997 I found one *D. punctatus edwardsii* in south-central McDonough County. So the species also came from the Illinois River bluffs to the southeast. Recent records (Thurow and Sliwinski, 1991) place *Diadophis* in the tributaries of McKee Creek (Brown Co.), the LaMoine River (Schuyler Co.), and the Spoon River (Fulton Co.). I have since found it further up the Spoon River (near Seville), and further up the LaMoine River (south McDonough Co.). I also saw seven 1997 specimens in the Sugar Creek drainage (an Illinois River tributary between the LaMoine and Spoon rivers) just south of southeast McDonough County. In the 1980s a student reported seeing *Diadophis* from southeast McDonough County but I thought he might have seen *Storeria occipitomaculata*.

I confirmed the two west county locations in 1997, and rechecked the subspecies. The western race has spread to southwest McDonough County near Colmar, and the northern race from the east has spread up the LaMoine through Schuyler County. The stream tributary with the south *D. punctatus edwardsii* joins the river only nine km from the Colmar railroad bridge. Surviving habitat and specimens are scarce. I have not confirmed obvious gene flow between the races, but one animal from west McDonough County (WIU 661) and one seen near Colmar in 1997 did indicate possible intergradation.

29) *Heterodon platyrhinos* - is characteristically a solitary and uncommon species. Twenty five years ago groups of late summer hatchlings could be found in Macomb, but now the snake is increasingly rare. It is particularly killed because of its poison-mimic bluff behavior, and the population was further depressed because of a food (*Bufo*) decline after the 1988 drought. Specimens include WIU 649 and INHS 7180, 12701. Photographs exist of normal and albino individuals from a farm in Fulton County.

30) *Storeria occipitomaculata* - is an uncommon to rare snake throughout Illinois (Smith, 1961). I found a few individuals south, west, and southwest of Macomb, usually on wooded slopes (WIU 351, 654). While rarely seen, the snake has been found repeatedly in a few locations, usually in late March or September.

31) *Thamnophis proximus* - is usually found near water, and was always more uncommon than *T. sirtalis*. *T. proximus* was found at scattered county sites, including Macomb and the WIU campus (WIU 504, 14144-5). The snake is rare today because of habitat loss. A few colonies probably survive, but only a few single animals have been seen in more recent years.

32) *Virginia valeriae* - is a secretive form that has been found at several localities in the south half of the county, near the LaMoine and its tributaries (WIU 350, 422). The snake occurs just north of the east fork of the river in a few places, including Macomb. Though generally rare, I saw 14 specimens in two hours at one locality. Another was seen nearby in 1997.

Very Rare or Extirpated Species, or Those of Unknown Status - Amphibians

33) *Eurycea cirrigera* - is a salamander that was introduced as an experimental range extension (Thurow, 1997). It currently is known to survive in only three small colonies in McDonough County, but should persist for many years.

34) *Hemidactylium scutatum* - is a state-threatened salamander (Illinois Endangered Species Protection Board, 1994) with one known relict colony in the county (Frankland, 1980, INHS 10616). Most of the breeding stream and surrounding high quality hard maple forest was protected by an earlier landowner. However, the area was logged around 1992, and again after 1994. Repeated attempts to buy the land or interest land preservation organizations were unsuccessful. The heavy machinery caused erosion which damaged the breeding stream by siltation. Careful searching in 1993 revealed no larvae where there had been many earlier, five larvae and some recovery in 1994, and poorer conditions and no larvae in 1997. Some adults probably survive, but with no breeding and continued habitat destruction the colony will probably be extirpated in a few years.

35) *Rana clamitans* - was missing from the county after a 30 year search. *Rana clamitans* has been reported for surrounding counties (Smith, 1961, and Thurow and Sliwinski, 1991), in adjacent McKee Creek and Spoon River and Mississippi drainages. I released 58 frogs (from Pike, Brown, and Hancock counties) and about 500 tadpoles from Hancock County into two adjacent sites near the LaMoine River from 1986-1993. In 1996 I saw two *R. clamitans* (GRT 3253) in a stream less than two km upriver, which

hints that the translocations may succeed. I had seen none there in my previous annual visits from 1987-1995.

36) *Rana pipiens* - is mostly found north of McDonough County, as mapped by Redmer (1996). It has also been seen in Mercer County, and other parts of Knox and Rock Island counties (Thurow and Sliwinski, 1991). Repeated efforts to find the northern leopard frog around McDonough County have failed. However, I did collect and/or identify about five specimens on my farm from 1990-1994 (Thurow and Sliwinski, 1991, GRT 3254). None were seen since, and I have not yet been able to confirm occurrence along the north border of the county. Possibly some tadpoles were inadvertantly brought in with a sample of pondweeds from Lake Bracken in Knox County south of Galesburg, or from a WIU campus pond where others have released "surplus" biological supply house frogs. *R. pipiens* should not be considered part of the McDonough County fauna without further confirmation.

Very Rare or Extirpated Species, or Those of Unknown Status - Reptiles

37) *Apalone muticus* - is not known from the county. I saw two that students brought in from Iowa, and Don Moll found them by the Mississippi River in Hancock County (personal communication). The species is said to prefer clear rivers with sandy bottoms (Minton, 1972, Parmalee, 1955, and Smith 1961), and the turbid LaMoine is probably not suitable today.

38) *Graptemys geographica* - was once present in the county. A small creek passed through Macomb and the WIU campus. Near 1900 there was so much seepage from glacial deposits that people dammed the stream to form Holmes Lake, (or Lake George), now empty. Clear calcareous water supported many *Sagittaria* plants which still were present along the creek in the 1960s, presumably with many aquatic snails. I collected two *G. geographica* then (WIU 76), and locals spoke of more turtles in earlier years. Homes were built throughout the stream drainage, which is largely dry today, and the *Sagittaria*, snails, and map turtles are all gone. The quality of many other county streams also declined, and this turtle is probably extirpated county-wide. Don Moll trapped the LaMoine River in the 1970s but no *Graptemys* were caught (personal communication).

39) *Graptemys pseudogeographica* - may never have occurred in the county, and no specimens or reports are known to me.

40 and 41) *Terrepene carolina* and *T. ornata* - do not occur naturally although both of their known ranges are nearby (Smith, 1961, and Thurow and Sliwinski, 1991). These two forms and *T. c. triunguis* have been found repeatedly in Macomb (one noted by Smith, 1961, possibly INHS 3495), but are presumably pet releases or escapes.

42) *Ophisaurus attenuatus* - is a lizard that may once have occurred in the county in relict hill prairies. I know of no specimens, although a few old WIU specimens with no data could possibly have come from this area. Today the "glass snake" is probably absent.

43) *Agkistrodon contortrix* - was present in past years according to local reports from south McDonough County near Fandon and Industry. Some old WIU specimens with no

data may be from the county. Today copperheads occur in small relict colonies just south of the county line (live specimens displayed by Michael Romano and Robert Sliwinski of WIU). These snakes are very rare but not yet extirpated in McDonough County, because one live juvenile from southwest of Macomb was donated to Michael Romano in the fall of 1997.

44) *Clonophis kirtlandii* - is a state-threatened snake (Illinois Endangered Species Protection Board, 1994) which was reported from southwest McDonough County (Clark, 1962), and one older WIU specimen (14138) is from Argyle Lake. After wet prairies were plowed and drained, this species was probably extirpated. I searched for it, but only found one in southwest Adams County in 1985 (WIU 14140).

45) *Crotalus horridus* - is a state-threatened species (ibid., 1994) which formerly lived near Industry (personal report from a citizen who grew up there), Walnut Grove (a secondhand report), and near "rattlesnake den hollow" north of Colmar between 1896 and 1914 (Selters, 1982). Some old WIU specimens with no data could be from the county. But no recent specimens have been found, and no recent reports from nearer than Pike, Scott, and possibly Brown counties to the south. Consequently the species is thought to be extirpated from McDonough County.

46) *Elaphe vulpina* - has been reported from surrounding Hancock, Adams, Warren, and Fulton counties (Thurow and Sliwinski, 1991), and from isolated records to the south (Smith, 1961). Road kills on Illinois Highway 67 extend south towards McDonough County (WIU 347), and there was one unconfirmed secondhand report from Good Hope. The range may be expanding south and may reach this county if it has not already.

47) *Lampropeltis getula* - is almost certainly absent now. However, a 74 year old man who grew up in southeast McDonough County gave me a good description of specimens from his youth, saying they were rare then. Smith (1961) does not show it quite to McDonough County, listing it as "probably occurring sporadically" in western Illinois, and cites an old Peoria record (Garman 1892). One was taken from southwest Pike County by a high school teacher in the 1970s, and another man described them as formerly present in Pike County in the 1950s. In more recent years one was taken from the vacinity of Camp Point in east Adams County, and was supposedly deposited at the Jacksonville High School. It was described as the only one encountered in 40 years.

48) *Lampropeltis triangulum* - is a species which was once widespread in Illinois but is now quite rare outside of captivity. It occurs in Pike County; one (early 1970s) record exists from the Mississippi bluffs in Hancock County (WIU 537); Quincy College had one from Adams Co.; and I found one more recently in Warren County, to the north. This snake is probably extirpated in McDonough County.

49) *Nerodia erythrogaster* - occurs in the Illinois River above and below the mouth of the LaMoine River (Smith, 1961), and I saw nearer Illinois River specimens in Pike and Schuyler counties. Dr. Robert Henry and Mrs. Alice Henry, both experienced field biologists, described a close-up pond edge sighting from a boat on their McDonough County property by the LaMoine in 1997. This rare snake is hard to approach closely, and from a

distance is difficult to distinguish from other *Nerodia*. It is tentatively listed here with the county herpetofauna, pending confirmation of a population.

50) *Opheodrys vernalis* - is not known from the county, is presumably absent and has declined markedly in Illinois. *Opheodrys* may never have occupied McDonough County as implied by Smith (1961), but did occur in Galesburg 32 km north of the border. A man showed me where a hibernating aggregation had emerged from his cracked cement porch in 1985, and another citizen reported *Opheodrys* from the same area in earlier years. None were found in 1986, nor from a reported Fulton County locality.

51) *Pituophis melanoleucus* - is not known from the county, though a 1965 WIU specimen (259) was taken 6 km south in Schuyler County. Smith (1961) shows it from surrounding counties, and I saw one in Fulton County to the east in 1992. One report came from southeast McDonough County, for 40 years ago. This large snake is much persecuted and declining in Illinois, and is probably gone from McDonough County. It may never have been abundant, since it prefers sandy soil in Illinois (Schmidt and Davis, 1941, Smith 1961).

52) *Regina grahamii* - may have occupied McDonough County in the past, as it was once widespread along the rivers. No county records are known and it is presumed absent. Riverside habitat (with *Cephalanthus occidentalis* shrubs) like that of a previous sighting in Schuyler County was searched.

53) *Sistrurus catenatus* - is a state-endangered species (Illinois Endangered Species Protection Board, 1994) which still may be present, but would be very rare. There are still scattered reports from Warren, Knox, and other nearby counties and one from McDonough County by a graduate student in 1983, but WIU specimens are from only Warren County. Some old WIU specimens with no data might be from McDonough County and the snake might survive, but it is excluded here until confirmed.

54) *Thamnophis radix* - is a prairie upland snake, near the margin of its range, and does not persist well in McDonough County hayfields like *Storeria dekayi*. Warren County to the north has *T. radix* (Thurow and Sliwinski, 1991), and I found it in Galesburg (Knox County) in 1993. I thought it was extirpated in McDonough County, but found one road kill in 1989 (GRT 3255) and one in 1993 (GRT 3256), both in north McDonough County. It is very rare and could disappear.

55) *Tropidoclonion lineatum* - could possibly have occurred in McDonough County in the past, judging from the present disjunct range (Conant and Collins, 1991, and Smith, 1961). However, no records are known from the county.

DISCUSSION

This study suggests that 14 native amphibians and 21 native reptiles survive in McDonough County in 1998. Maps of the last major publication on Illinois herptile distribution (Smith, 1961) omitted the amphibians *Hemidactylium* and *Rana utricularia* (*R. pipiens sphenocephala*), and the more recently distinguished *R. blairi* and *Hyla chrysoscelis*. Smith's maps also implied that six of the reptiles were not in McDonough

County: *Carphophis, Diadophis, Thamnophis proximus, Virginia valeriae, Storeria occipitomaculata*, and *Nerodia* (*Natrix*) *erythrogaster*. Smith also shows *Lampropeltis getula* and *Clonophis* (*Natrix*) *kirtlandii* as being absent, although both probably once were present.

Smith's (1961) maps also indicated the probable presence of 12 native herptiles in McDonough County which I do not list here: *Rana clamitans* (though it has subsequently been introduced), *Rana pipiens* (the northern leopard frog), *Graptemys pseudogeographica* and *G. geographica* and *Ophisaurus attenuatus* (though he does not indicate these three by specific shading), *Apalone mutica, Opheodrys vernalis, Pituophis melanoleucus, Lampropeltis triangulum, Regina* (*Natrix*) *grahamii, Sistrurus catenatus*, and *Crotalus horridus*. A few additional species might still be found in McDonough County, such as *Rana pipiens, Clonophis kirtlandii, Elaphe vulpina*, and *Sistrurus catenatus*.

Eight of the 14 McDonough County amphibians are widespread (57%), five have restricted numbers or distribution (36%), and one (*Hemidactylium*) is on the verge of extirpation. Nine of the 21 reptiles (43%) are widespread in the county, nine are restricted, and three (14%) are very rare.

Four native salamanders and 10 frogs now live in McDonough County, of which *Hemidactylium scutatum* (rare) and *Rana utricularia* (found more recently) are noteworthy. No amphibian extirpations are known to have taken place in historical times. Their ranges and environmental change (Pielou, 1991) indicate that *Rana clamitans* and *R. sylvatica* probably once occurred and later disappeared, but they have been introduced again. Still more salamanders have been successfully translocated (but not all reported here), so the amphibian biodiversity of the county has not decreased yet, although many population sizes have.

Reptile biodiversity on the other hand has suffered greatly. Five turtles remain. But one and possibly two or more have been extirpated. One of two probable former lizards barely remains. Only 15 snakes remain, and nine of these show notable decline. At least five more probably existed in recent times. Six reptile survivors are less expected and therefore more noteworthy: the snakes *Carphophis, Diadophis* (both prairie and northern races), *Virginia valeriae, Thamnophis radix, Nerodia erythrogaster,* and *Agkistrodon contortrix.*

In recent years much attention has been given to a worldwide decline in amphibian biodiversity (Blaustein, 1994; McCoy, 1994; Phillips, 1994; Pechman and Wilbur, 1994; Travis, 1994; and many others), but comparable attention has not been given to reptiles. Reptiles are higher on the food chain and require populations of food animals supplied by relatively healthy ecosystems. Reptiles cannot exist on soil microarthropods, or algae or zooplankton, like many salamanders and frog larvae. Furthermore, reptiles are generally larger and more active, and require larger areas for self-sustaining breeding populations. The same amount of habitat fragmentation, selective lumbering or other disruption can be critical for a reptile population, but more tolerable by smaller amphibians during subsequent habitat recovery. Reptile augmentation or restocking is more difficult for these reasons. Reptiles are often more widely scattered, and it is more difficult to find the criti-

cal minimum number of donors to establish a population, particularly from the local area. Unfortunately, snakes, the most numerous reptile group in many areas, are more deliberately persecuted by humans than other herptile groups.

In many counties of the eastern U.S., reptile biodiversity is declining, and not just in counties that are becoming more metropolitan (as in Minton, 1968). This is also occurring in agricultural counties, like McDonough, where most of the original habitat has been replaced by crops.

Amphibians also have other problems in McDonough County besides habitat loss and degradation. Farmers and others use fertilizers, and pesticides. After the spring rains and runoff from fields, the mutagenicity of the waters increases (Ma, et al. 1985). My field notes record oily films on some ponds in some years, and some probable disappearance of amphibian larvae other than by predation or metamorphosis. The effects of acid rain are not extreme, probably because of the buffering effect of calcareous glacial deposits, and the addition of ground limestone for agriculture. I have not yet seen obvious intersexes or teratogenic abnormal development. In general, the amphibians appear to breed successfully. One or more pathogens in McDonough County sometimes cause a disease resembling "red leg", although most amphibians are unaffected. Erythema, edema or blister-like lesions, and necrosis sometimes occur. Around 1990 I found a dead *Rana blairi* with this condition in Wigwam Hollow Creek west of Macomb. In 1993 some *R. sylvatica* tadpoles showed this condition in an overcrowded puddle near lower Miller Creek northeast of Macomb. Unlike most of their siblings, they failed to metamorphose. In 1997 some salamander larvae briefly showed this condition in a crowded streamside impoundment (pictured by Thurow, 1994b) further up Miller Creek, and some mortalities resulted. Tadpoles, frogs, and other herptiles were apparently not affected.

Studies concerning long term herptile population changes are beginning to appear. Lanoo et al. (1994) noted changes among nine amphibians in Dickinson County, Iowa. Two had not been found from 1920, and two others were not present in 1920. McAlpine (1997) found evidence suggesting less change among 16 amphibians in New Brunswick, Canada.

Private citizens could slow herptile species losses by: 1) supporting natural land acquisition and protection organizations, and 2) by refraining from killing reptiles and educating others to do likewise. Since reptile populations often need larger areas of habitat (perhaps 32 ha or more), it may be practical for people to pool their efforts in raising money to purchase land or agreeing to protect bordering adjacent habitat areas. Although one small "odd corner" is usually insufficient, it can sometimes be helpful if contiguous with a watercourse or railroad, or even a road or fence row. Conservation easements can be used to protect habitat beyond the present owner's lifetime.

ACKNOWLEDGMENTS

I would like to thank the many students and other people who assisted me over the years. Chris Becker, made a county wide survey for leopard frogs around 1990. Dr. Don Moll donated much turtle information. The Illinois Department of Natural Resources provided collecting permits and two grants supporting translocation projects. Ken Russell provided additional *Sistrurus* sightings in neighboring counties. The following museum curators or caretakers supplied information: Ron Vasile (Chicago Academy of Science), Harold Voris (Field Museum of Natural History), Edward Moll (Eastern Illinois University), Lauren Brown (Illinois State University), Christopher Phillips (Illinois Natural History Survey), Mrs. Lee Farrar (Knox College), Harlan Walley (Northern Illinois University), and Ralph Axtell (Southern Illinois University at Edwardsville). Figure 1 was prepared by Scott Miner of the WIU Cartography Laboratory.

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Figure 1. McDonough County. Dark areas represent forests in 1963. Light areas are primarily agriculture.

162

Student Research Grant Awards

Monique Baumel
Loyola University

Olmec agriculture in Mixico: a palynological perspective.

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Transactions of the Illinois State Academy of Science
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CONTENTS

Academy of Science Editorial Information ..... inside front cover

Agriculture Papers

A.B. Anderson, A.B., L.J. Frampton, and R.J. Weir
Shoot Production and Rooting Ability of Cuttings From Juvenile Greenhouse Loblolly Pine Hedges 1

Botany Papers

Akers, Brian P., Walter J. Sundberg, and Virginia A. Skeel
Allopatric Spore Ratio Variation in *Leucoagaricus hortensis* (Agaricales, Basidiomycetes), a Species New to Illinois 15

Applebee, Tami A., David J. Gibson, and Jonathan A. Newman
Elevated Atmospheric Carbon Dioxide Alters the Effects of Allelochemicals Produced by Tall Fescue on Alfalfa Seedlings 23

Basinger, Mark A.
Notes on some Naturalized Woody Plant Species New to Illinois 33

Phillippe, Loy R., Jennifer A. Tate, David M. Ketzner, and John E. Ebinger
Vascular Flora of Chauncey Marsh Natural Area, Lawrence County, Illinois 37

Tyson, W. Stan and John E. Ebinger
Distribution and Ecology of *Corydalis curvisiliqua* Engelm. var. *grandibracteata* Fedde (Papaveraceae) in Illinois 53

Vordtriede, Sarah A., Paul B. Vordtriede, Kurt E. Schulz, Frank B. Kulfinski, and Mark G. Bolyard
Embryo Germination in *Acer ginnala* Maxim. and the Activity of an Endogenous Exudate 59

Environmental Science Papers

Bluett, Robert D., Edward A. Anderson, George F. Hubert, Jr., Glen W. Kruse, and Susan E. Lauzon
Reintroduction and Status of the River Otter (*Lutra canadensis*) in Illinois 69

Zoology Papers

Garthause, Michael W. and Roy C. Heidinger
Response of Largemouth Bass and Bluegill to Length Limits in Lake of Egypt 79

Havera, Stephen P. and William L. Anderson
Food Contents of Mallard Gizzards With and Without Ingested Lead or Steel Shot .. 89

Hofmann, Joyce E., James E. Gardner, Jean K. Krejca, and James D. Garner
Summer Records and a Maternity Roost of the Southeastern Myotis (*Myotis austroriparius*) in Illinois 95

Kobal, Scott N., Neil F. Payne, and Daniel R. Ludwig
Habitat/Area Relationships, Abundance, and Composition of Bird Communities in 3 Grassland Types 109

Kolbe, Jason J., Luke J. Harmon, and Daniel A. Warner
New State Record Lengths and Associated Natural History Notes for some Illinois Snakes 133

Taylor, Christopher A. and Thomas G. Anton
Distributional and Ecological Notes on some of Illinois' Burrowing Crayfishes 137

Thurow, Gordon R.
Herpetofaunal Changes in McDonough County, Illinois 147

Awards and Announcements 163

Contributor Information ..... inside back cover

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TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

Volume 92, Numbers 3 and 4 1999

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907

Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 167-179

received 6/12/98
accepted 3/6/99

Effects of Nitrogen Fertilizer and Defoliation on Growth, Foliar Nitrogen, and Foliar Coumestrol Concentrations of Soybean

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ABSTRACT

Growth of plants and resistance to pathogens and herbivores can be altered by a variety of environmental factors, including nutrient availability and defoliation. Using *Glycine max* cv. G3197, a cultivar tolerant of phytophthora rot, we tested the predictions that (1) nitrogen fertilizer would enhance and defoliation would reduce vegetative growth and reproduction, and (2) nitrogen fertilizer would decrease and defoliation would increase concentrations of coumestrol, an isoflavonoid produced in response to a variety of stimuli and associated with decreased performance of insect herbivores. Individual plants were fertilized with a nitrogen-free basal fertilizer and either 2.5 mM NH_4NO_3 or water throughout the six weeks of growth. Half of the soybeans were partially defoliated 4 weeks after germination by cutting off the distal half of all fully expanded leaves. Two weeks later plants were harvested, dried, and weighed. Nitrogen fertilizer increased shoot mass and defoliation decreased root mass but effects were not strong and varied among the four groups of replicate plants. Foliar coumestrol concentrations of uncut leaves declined with nitrogen fertilizer but were not consistently linked to defoliation. Nitrogen concentrations of leaves were not consistently associated with nitrogen fertilizer or defoliation. Nutrient availability and defoliation significantly altered plant growth and chemistry, but in this experiment the strength of such factors was in turn influenced by unidentified environmental variability.

Key words: clipping, resistance, isoflavonoids, environmental variability

INTRODUCTION

Environmental conditions affect growth and chemical content of plants, which in turn determine resistance to pathogens and herbivores. Factors such as soil moisture (McQuate and Connor, 1990a,b; Lambert and Heatherly, 1991; Jenkins et al., 1997), soil fertility (Chang et al., 1985; Manuwoto and Scriber, 1985), mycorrhizal infection (Davis

and Menge, 1981; Rabin and Pacovsky, 1985; Gange and West, 1994; Gange et al., 1994; Matsubara et al., 1995), light (Kennedy et al., 1981; Elden and Kenworthy, 1995), temperature (van de Klashorst and Tingey, 1979; Ward and Lazarovits, 1982; Ratanatham and Gallun, 1986), previous damage (Reynolds and Smith, 1985; Lin and Kogan, 1990; Bi et al. 1994), and agrochemicals (Rose et al., 1988) can enhance or negate resistance to insects and pathogens. Because these environmental factors are varied and often unpredictable, development of lines resistant to insect pests and pathogens can be difficult. Breeding soybean for resistance to defoliating insects such as Mexican bean beetle (*Epilachna varivestis* L.) is a case in point. Although numerous cultivars have been bred for resistance, concern that resistance may break down with plant maturity and environmental conditions such as temperature has resulted in limited release to growers (Hammond et al., 1995; Jenkins et al., 1997).

Not only do crops experience a variety of environmental conditions that influence expression of resistance, they may also suffer attack by more than the pest or pathogen for which they were selectively bred. Consequently, it is useful to take a less focused approach and consider responses of cultivars to environmental factors beyond those for which breeding was targeted. Studies that examine effects of interacting environmental factors on underlying mechanisms of resistance can test predictions of hypotheses proposed to explain patterns of plant-herbivore or plant-pathogen relations and may provide insight for future crop breeding strategies.

In this study we examined growth and foliar concentrations of nitrogen and coumestrol of soybeans, *Glycine max* (L.) Merr., grown under two nitrogen and defoliation regimes. The cultivar, G3197, exhibits tolerance to the fungal root pathogen *Phytophthora sojae* (M. Miles, pers. comm.). Tolerance refers to the relative ability of plants to sustain pathogenic infection without exhibiting severe disease symptoms (Walker and Schmitthenner, 1984), or more generally, the ability to withstand damage without incurring loss of productivity (Deverall, 1982). Tolerant cultivars can be a viable alternative to cultivars with race-specific resistance, which have been selected for new races of pathogens (Smith, 1985; Schmitthenner, 1985; Ryley et al., 1989).

We restricted our investigation to the effects of treatments on early growth of plants and foliar concentrations of nitrogen and the isoflavonoid coumestrol. Coumestrol is an estrogen-based phytoalexin (Smith, 1982), which is a metabolite that undergoes increased or de novo synthesis and accumulates in plants following exposure to a variety of stimuli (Paxton, 1980; Deverall, 1982). Coumestrol can deter feeding (Sutherland et al., 1980; Burden and Norris, 1992) and reduce performance (Rose et al., 1988) of herbivorous insects and it has some antimicrobial properties (Weinstein and Albersheim, 1983). Production of coumestrol has been induced by light, wounding, and by a wall glucan elicitor preparation from *P. sojae* (Graham and Graham, 1996). Induction of coumestrol in *Phaseolus vulgaris* L. leaves by ultraviolet radiation has been shown to increase with plant age and water or mineral stress (Beggs et al., 1985).

An increase in carbon-based defense compounds in mineral-stressed plants can occur if photosynthesis is sink-limited and plants accumulate carbohydrate reserves (Chapin et al., 1990). Surplus carbohydrates may be shunted to secondary metabolic pathways that produce non-nitrogenous defense compounds (Bryant et al., 1983). Because well-nourished

plants have the resources to use fixed carbon in primary metabolic pathways, they are predicted to have lower levels of carbon-based defense compounds when undamaged. Instead, they may be defended by nitrogen-based compounds (Bryant et al., 1983). This inverse relationship between carbon-based defenses and nitrogen availability has been demonstrated for phenolics in fir trees (Muzika, 1993). However terpenes, which are also carbon-based compounds, did not respond to nitrogen fertilization, suggesting that production of carbon-based resistance compounds are not invariably linked to nitrogen availability (Muzika, 1993).

Coumestrol production is induced by damage (Graham and Graham, 1996). We predicted that damage caused by clipping leaves would increase concentrations of coumestrol in uncut leaves of both nitrogen-stressed and nitrogen-fertilized plants, but in the absence of clipping, nitrogen-stressed plants would have higher levels of coumestrol than would nitrogen-fertilized plants. We predicted that addition of nitrogen fertilizer would increase growth and reproduction.

MATERIALS AND METHODS

Plants

Due to time constraints the experiment was conducted in four parts (= "groups") that were started at three or four day intervals over the course of 11 days. Each group consisted of two plants from each treatment combination. Seeds for each group were surface sterilized in 20% bleach for one minute and germinated on wet paper towel at the same time. Germinated seeds were planted in 3.75 L pots containing autoclaved 3:1 prairie topsoil:perlite and randomly positioned (using random number table) in a greenhouse under artificial light which extended the daylength to 14 h. Pot positions within a group and the entire groups were rotated daily.

Each plant was assigned one of two nitrogen treatments after being placed in the pots: no added nitrogen or nitrogen added as fertilizer. All plants were fertilized daily with 200 ml of nitrogen-free basal fertilizer (Pacovsky and Fuller, 1988). Half of the plants were fertilized to excess with 2.5 mM NH_4NO_3 and the remaining were watered to excess with water. Four weeks after planting, half of the plants in each fertilizer treatment were partially defoliated by clipping off one half of each fully expanded leaflet. The clipped portions were lyophilized and weighed.

Two weeks after the clipping treatment all plants were harvested and divided into seven major components:

1 reproductive tissue
2 nodules
3 nodule-free roots
4 clipped leaves on clipped plants, leaves of similar age on unclipped plants
5 expanded, uncut leaves
6 unexpanded leaves
7 remaining aboveground tissue (stems, petioles)

Leaves (components 4 - 6) were lyophilized, weighed, and stored at -35°C. All other tissue was oven-dried and weighed. Components 5 and 6 were pooled within plants and analyzed for % nitrogen and coumestrol concentration (µg coumestrol mg^{-1} dry leaf mass).

Nitrogen assay

Nitrogen was analyzed following a modification of the procedure of Robyt and White (1987). For each plant a 100 mg sample of ground, lyophilized leaves was digested in 5 ml of 7.5% (wt/v) sodium sulfate in 18 N sulfuric acid by heating to boiling, cooling, and adding 30% hydrogen peroxide dropwise over low heat until the mixture stopped bubbling and cleared. After cooling, the volume was brought up to 35 ml. Then 0.5 ml of sample was mixed with 0.1 ml Rochelle salt, 3.0 ml Nessler's reagent, and 6.4 ml distilled water and absorbance was measured at 506 nm. Digests were assayed in duplicate and the two values were averaged. Ammonium sulfate was used as a standard with a range of 0 to 1.29 µg N ml^{-1}. Assays were done by group and a standard curve was established for each group using the linear or quadratic function that provided the best fit. Data are reported as percent nitrogen per dry weight of leaf.

Coumestrol assay

Coumestrol was analyzed using a modification of the method of Burden and Norris (1992). For each plant a 250 mg sample was homogenized in 20 ml methanol and filtered through #1 Whatman filter paper. This filtrate was discarded after TLC analysis showed absence of coumestrol in this fraction. Fifty ml of methanol were added to the residue and the sample was shaken for 16 hours and vacuum filtered through #1 Whatman filter paper. The shaking and filtering was repeated and the two filtrates for each plant were pooled. The pooled sample was reduced to 2-4 ml by rotoevaporation, filtered through a 2.0 micron BS filter (Millipore, Milford, MA), and the volume was adjusted to 2 ml. Extracts were filtered using Sep-pak plus® C18 cartridges (Millipore, Milford, MA).

To confirm that there was no coumestrol loss due to the Sep-pak plus® C18 cartridge, a sep pak cartridge was prewet with 1 ml of water. Extract (400 µl) was eluted through the cartridge and the fraction was collected. The cartridge was washed (2X) with 400 µl of methanol and each of the three fractions was analyzed by HPLC to determine the coumestrol peak. For each fraction a 20 µl injection was analyzed by reversed phase HPLC using an ODS column and a 3 solvent elution system modified from Burden and Norris (1992). The pump flow rate was 1ml min^{-1} and the elution step gradient was solvent A (90:10 (v/v) 2% acetic acid:acetonitrile) for 5 min, solvent B (50% solvent A + 50% solvent C) for 10 min, and solvent C (100% acetonitrile) for 15 min. The elute was evaluated at 254 nm. The area under the peak which eluted at 19 min, the elution time for authentic coumestrol, was calculated for determining the apparent concentration of coumestrol. To confirm the identity of coumestrol by elution time, the fraction at the expected elution time was collected, dried under N_2 then chromatographed on an Alufolien plate using 80:20 (v:v) water/methanol as solvent. The presence of coumestrol was determined by presence under short-wave UV light of fluorescent spots which co-migrate with authentic coumestrol. A standard curve using authentic coumestrol (Spectrum Lab, Gardena, CA) was constructed ranging from 0.08 to 0.72 µg coumestrol. Data are reported as µg coumestrol mg^{-1} dry leaf mass.

Statistical analysis

Vegetative shoot mass (components 4 - 7), reproductive tissue, and dry root mass (components 2 + 3) were treated as univariates in a multivariate analysis of variance (MANOVA, SAS Institute Inc. 1989) using a three-way mixed effects model. Group (1-4) was treated as a random effect and nitrogen fertilizer (no, yes) and clipping (no, yes) as the fixed effects nested in group. When main effects were significant multiple pairwise comparisons of least-squares means were performed using the sequential Bonferroni method (Rice, 1989) at experimentwise $\alpha = 0.05$. This resulted in 4 comparisons if only one fixed effect was significant, 8 comparisons if both nitrogen and clipping treatments were significant, and 16 comparisons if there was a significant interaction. To meet the assumptions of normality and homoscedasticity the reproductive tissue data were square-root transformed and the root data were rank-transformed.

Percent nitrogen and coumestrol concentration were univariates in a multivariate analysis of variance (MANOVA) with group as a random effect and nitrogen fertilizer and clipping as fixed effects nested in group. Sequential Bonferroni comparisons were performed as needed. Coumestrol data were squared to meet assumptions of analysis of variance.

RESULTS

Biomass

Nitrogen fertilizer, clipping, and group significantly affected the pattern of soybean growth (MANOVA -Table 1). The magnitude of standardized canonical coefficients indicate that the multivariate effect was primarily due to effects on vegetative shoot mass (Table 1). Shoots constituted the largest portion of the biomass and so factors that improved growth tended to have the greatest absolute effect on shoots. However, most of the variation due to clipping was explained by root mass, indicating that clipping had a greater effect on roots than on shoot mass (Table 1).

The pattern of allocation to the three biomass components was constant across nitrogen and clipping treatments, as indicated by positive standardized canonical coefficients (Table 1). Addition of nitrogen tended to increase growth and clipping tended to decrease growth. However, the effects of nitrogen were significant only for the two shoot components (significant F tests, Table 1) and then only in some pairwise comparisons of nitrogen treatments within groups (Fig. 1a,b). Clipping significantly affected vegetative shoot mass and root mass (Table 1), but the reduction in growth was significant only in some pairwise comparisons of clipping treatment within groups (Fig. 1d,f). Nitrogen and clipping treatments did not interact (Table 1), indicating that the response to clipping did not depend upon nitrogen availability.

Plant group had a strong effect on all biomass components but the nature of the effect was not consistent across components (Table 1). Mean vegetative shoot mass was significantly smaller in group 4 than in group 1 ($P=0.0005$) and 3 ($P=0.0004$), mean mass of reproductive tissue was greater in group 4 then in group 2 ($P=0.0005$), and mean root mass was smaller in group 2 than in group 1 ($P= 0.0012$) or group 3 ($P=0.0076$). Thus,

fertilizer and clipping treatments had qualitatively similar effects across groups, but the magnitude of the effects varied among plant parts within groups.

Plant chemistry

Nitrogen fertilizer, clipping, and group significantly affected foliar concentrations of nitrogen and coumestrol. The magnitude of standardized canonical coefficients indicates that effects on coumestrol concentration explained most of the variation due to the fixed effects (Table 2). The relationship between nitrogen and coumestrol concentrations tended to remain constant among treatments (standardized canonical coefficients all positive - Table 2).

Nitrogen fertilizer significantly affected foliar nitrogen concentration (Table 2) and the trend was towards greater nitrogen concentrations in the foliage of nitrogen-fertilized plants (Fig. 2). However, the size of the effect was significant in only two groups and those two groups exhibited opposite trends (Fig. 2). Nitrogen-fertilized plants had significantly higher foliar nitrogen concentration than unfertilized plants in group 2, but had significantly lower concentrations than unfertilized plants in group 4 (Fig. 2). Clipping did not significantly affect foliar nitrogen concentration (Table 2).

Both nitrogen fertilizer and clipping treatments affected coumestrol concentrations (Table 2). When significant, the effect of nitrogen fertilizer on coumestrol concentration was consistent regardless of clipping. Nitrogen fertilizer decreased coumestrol concentration in unclipped plants in groups 1 and 2, and also decreased coumestrol concentration in clipped plants in group 3, and marginally in groups 1 and 2 (Fig. 3). Effects of clipping were less clear. Clipping significantly affected coumestrol concentration but only among unfertilized plants and the direction of the effect differed between groups (Fig. 3).

A fungal pathogen was observed on one or more plants in each group by the time of harvest and seven of the eight plants in group 4 had a significant number of infected leaves. Although leaves used in chemical assays were fungus-free, systemic induction of coumestrol could have elevated levels in the leaves we analyzed. We examined the correlation between coumestrol concentration and the proportion of leaf mass attacked by the fungus to determine whether coumestrol concentration was associated with the pathogenic infection. Coumestrol concentration was not correlated with severity of fungus infection for either clipped (Pearson correlation, $r = 0.19980$, $P = 0.4581$), or unclipped leaves ($r = 0.096545$, $P = 0.7223$).

DISCUSSION

The effects of nitrogen and clipping on growth and chemistry of soybeans were in general agreement with predictions based on published accounts and hypothesized models. Nitrogen fertilizer increased growth and decreased foliar coumestrol concentrations. Clipping decreased growth but had variable effects on coumestrol concentrations. The effects of these treatments were not pronounced and varied considerably among groups.

The large and varied effect of group (as defined earlier) was surprising, considering that this experiment was conducted in a small 4.5 m^2 greenhouse that was on the west side of the building and was partially covered by a tree thus reducing the effects of small varia-

tions in the weather. Although more controlled than in a field setting, factors such as light intensity and temperature fluctuate inside a greenhouse with daily changes in cloud cover and air temperature. Some fluctuations in environmental factors in a greenhouse can significantly affect plant growth (Summerfield, 1976; Potvin, 1993). Because small numbers of replicates were harvested at intervals, such fluctuations could have caused differences among groups without producing a discernible pattern.

Addition of nitrogen significantly increased shoot but not root growth. Changes in root:shoot investment are predicted if plants adjust resource allocation to minimize resource limitation (Mooney, 1972; Bloom et al., 1985), although see Coleman et al. (1993) for other outcomes. In our study addition of fertilizer created an imbalance between carbohydrates and nitrogen, and plants responded by investing less in roots for nutrient uptake and more in shoots for carbon fixation. Similarly, defoliation reduces photosynthesis and thus creates an imbalance in the ratio of carbon to nutrients (Bryant et al., 1983). As with addition of fertilizer, plants responded to the nutrient imbalance resulting from clipping by producing relatively less root and relatively more shoot mass.

We predicted that addition of fertilizer would not only increase growth but also increase the nitrogen concentration in leaves. This could occur if nitrogen fertilizer provides nitrogen in surplus and plant growth becomes limited by some other factor. A significantly greater nitrogen content of leaves in group 2 was associated with a marginally significant increase in vegetative shoot mass. However, foliar nitrogen concentration in group 3 showed no change with increased vegetative shoot mass, and foliar nitrogen concentration for group 4 decreased with increased production of reproductive tissue. Rather than concentrate minerals these groups responded to increased nitrogen availability by making more plant tissue, apparently diluting nitrogen concentrations. A similar result was observed in *Polygonum pensylvanicum*, where a pulse of fertilizer increased vegetative and fruit mass but did not affect leaf nitrogen (Mabry et al., 1997).

As predicted, nitrogen fertilization decreased foliar concentration of coumestrol. This is in agreement with observations of decreased coumestrol concentrations in roots of nitrogen fertilized "Amsoy 71" soybeans (Morandi and LeQuere, 1991) and with predictions of the carbon/nutrient balance model (Bryant et al., 1983). According to this model, nutrient limited plants shunt surplus carbon to secondary metabolic pathways and produce non-nitrogenous defense compounds. When not nutrient-limited they use carbon fixed in photosynthesis for growth, resulting in lower levels of carbon-based compounds such as coumestrol.

Coumestrol is distasteful to some herbivores (Kogan, 1977) and can decrease survival rate of larvae that consume foliage protected by coumestrol (Kogan and Paxton, 1983). However the effectiveness of coumestrol as a deterrent is dose dependent. Levels of foliar coumestrol in our experiment were similar to levels reported by Burden and Norris (1992) for 'Davis' soybean (0.063 $\mu g\ mg^{-1}$). Although "Davis" soybeans have constitutive antixenosis, Burden and Norris (1992) found that the coumestrol levels were considerably lower than 0.7 $\mu g\ mg^{-1}$, the minimum concentration required to deter feeding by Mexican bean beetles. They speculated that coumestrol alone is not responsible for constitutive antixenosis, but contributes to a complex array of plant stimuli affecting herbivore feeding.

Clipping did not consistently affect coumestrol concentration. It is possible that coumestrol levels increased shortly after clipping but dropped during the two weeks between clipping and harvest. Although isoflavonoid concentrations often exhibit temporal variation (Bohm, 1987; Burden and Norris, 1992) they do not necessarily respond to damage. Coumestrol levels of "Davis" soybean were not altered significantly by application of p-chloromercuriphenyl sulfonic acid, which nonetheless induced resistance to soybean looper, *Pseudoplusia includens*, and increased levels of the phytoalexin glyceollin (Liu et al., 1993). Glyceollin is a phytoalexin associated with resistance to phytophthora (e.g., Ward et al., 1979; Hahn et al., 1985) and, with coumestrol, is part of the suite of chemicals that can deter both insect herbivores and pathogens. We did not analyze glyceollin levels and plants may have responded to clipping by increasing concentrations of this phytoalexin.

CONCLUSION

In our experiment, the pattern of soybean growth and concentrations of foliar nitrogen and coumestrol were in general agreement with predictions. Plants responded to nitrogen deficiency and defoliation in a manner that was consistant with the predictions of the carbon/nutrient balance model. However, variability among groups was high. Although significant in the greenhouse setting, small differences in response to levels of nitrogen and defoliation may be swamped out under field conditions, where spatial and temporal variation in additional features such as soil quality, drainage, and herbivore load are likely to be significant.

Despite strong selection for specific attributes, soybeans still possess some inherent plasticity in growth and allocation. This plasticity may provide the basis for tolerance to a breadth of factors detrimental to growth and productivity, and may be a useful feature to exploit in some agricultural systems.

ACKNOWLEDGEMENTS

We thank D.J. Schmidt, M. Miles, S. A. Juliano, and D. Hennricks for technical advice, and L. Khanna for assistance. This research was supported by grants from Sigma Xi and the Beta Lambda Chapter of Phi Sigma to A.Q.K. and USDA NRI Competitive Grants Program award # 91-37100-6595 to V.A.B.

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Table 1. MANOVA and ANOVA results for three biomass components of clipped or unclipped plants given nitrogen-free or 2.5 mM NH_4NO_3 fertilizer. Analysis of root mass was performed on rank transformed data and analysis of pod mass was performed on square root-transformed data.

Source	df	F-Shoot mass (P)	F- Root mass (P)	F-Pod mass (P)	Pillai's trace (P)	Standardized canonical coefficients shoot mass	root mass	pod mass
N(group)	4	7.36 (0.0015)	2.11 (0.1264)	3.36 (0.0355)	1.0996 (0.0200)	1.1041	0.6001	0.6971
Clip(group)	4	4.85 (0.0094)	7.22 (0.0016)	0.94 (0.4649)	1.2256 (0.0062)	0.6714	1.3091	0.2975
N x Clip(group)	4	1.05 (0.4112)	0.94 (0.4676)	0.50 (0.7354)	0.5118 (0.6267)	1.8759	-0.7164	-0.2421
Group	3	9.24 (0.0009)	5.72 (0.0074)	6.34 (0.0049)	1.4454 (0.0001)	-1.3702	1.0048	1.3066

Table 2. MANOVA and ANOVA results for nitrogen concentration and coumestrol concentration for clipped or unclipped plants given nitrogen-free or 2.5 mM NH_4NO_3 fertilizer. Analysis of coumestrol concentration was performed on squared data.

Source	df	F-nitrogen (P)	F- coumestrol (P)	Pillai's trace (P)	Standardized canonical coefficients nitrogen	coumestrol
N(group)	4	6.22 (0.0032)	72.12 (0.0001)	1.3609 (0.0001)	0.4970	4.7822
Clip(group)	4	1.12 (0.3819)	29.05 (0.0001)	1.0950 (0.0006)	1.1270	4.8959
N x Clip(group)	4	0.54 (0.7119)	35.27 (0.0001)	0.9893 (0.0026)	1.0667	4.8911
Group	3	113.38 (0.0001)	31.25 (0.0001)	1.2740 (0.0001)	3.4914	3.3066

Figure 1. Impact of nitrogen fertilizer (a-c) and clipping (d-f) on mass of lyophilized aboveground vegetative tissue, mass of oven-dried reproductive tissue, and rank of oven-dried root mass for the four groups ($\overline{X}$±1se). * significant pairwise comparison at overall $\alpha = 0.05$. (*) significant at overall $\alpha = 0.10$.

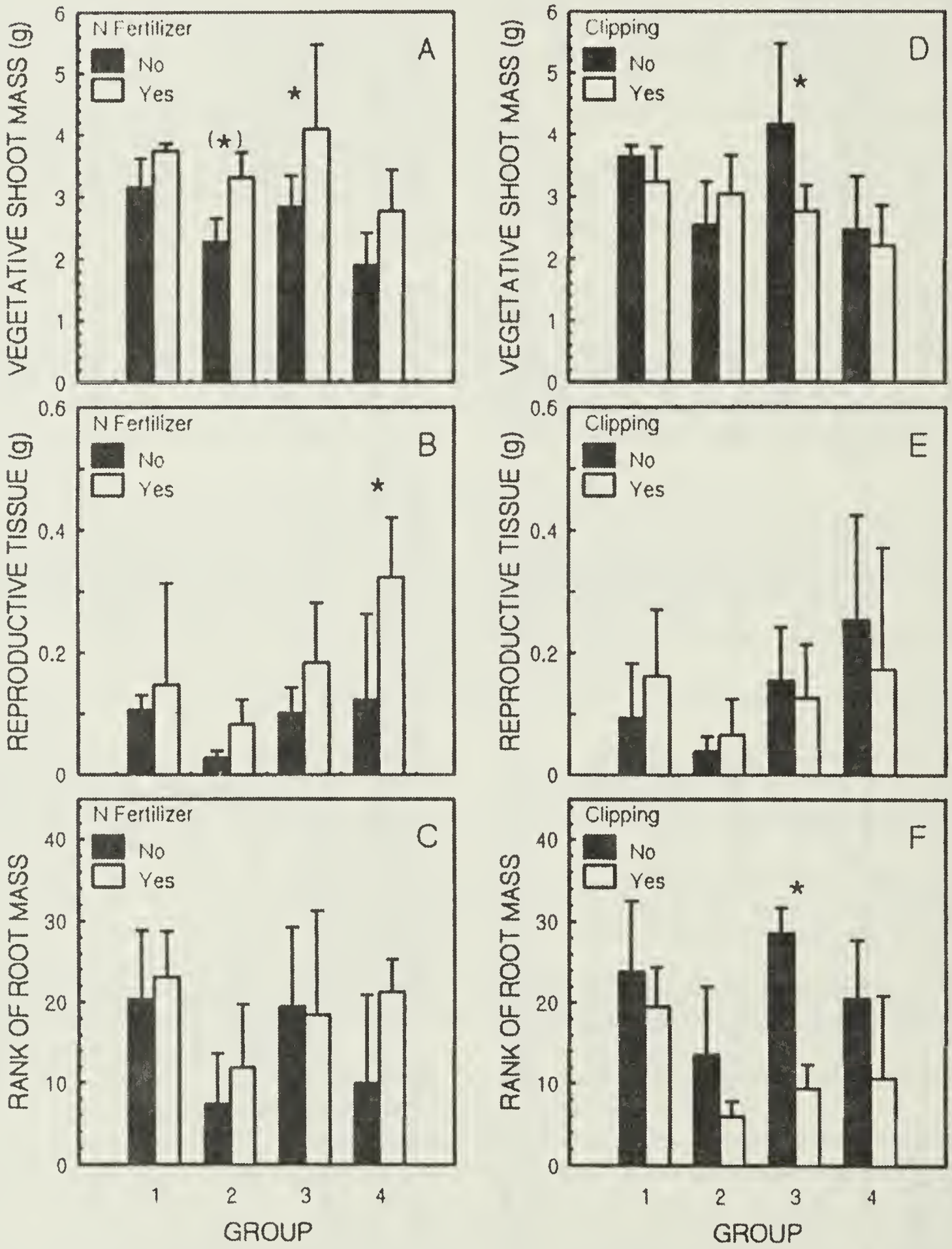


Figure 2. Impact of nitrogen fertilizer on nitrogen content of lyophilized leaves ($\overline{X} \pm 1se$) * significant pairwise comparison at overall $\alpha = 0.05$.

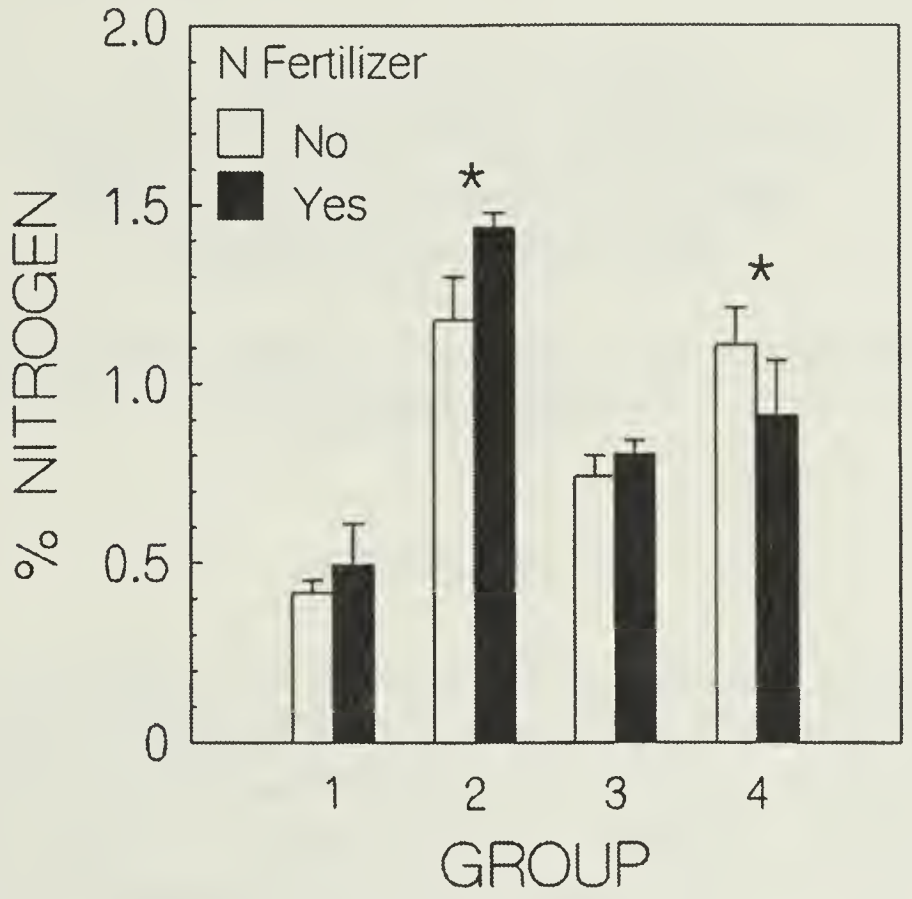
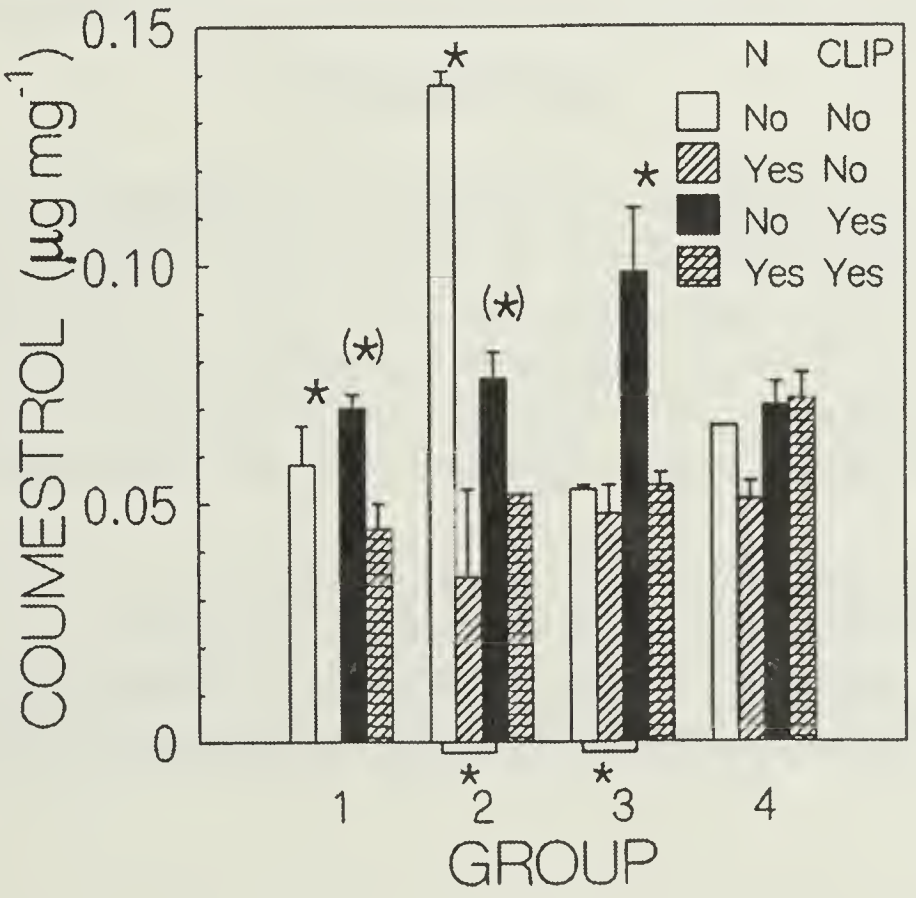


Figure 3. Impact of nitrogen fertilizer and clipping treatment on coumestrol content of lyophilized leaves ($\overline{X} \pm 1se$). * significant pairwise comparison at overall $\alpha = 0.05$. (*) significant at overall $\alpha = 0.10$. Brackets below the graph indicate pairs for which clipping was a significant effect.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 181-190

received 12/8/98
accepted 6/2/99

Syzygites megalocarpus (Mucorales, Zygomycetes) in Illinois

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ABSTRACT

Syzygites megalocarpus Ehrenb.: Fr. (Mucorales, Zygomycetes), which occurs on fleshy fungi and was previously unreported from Illinois, has been collected from five counties--Cook, Gallatin, Jackson, Union, and Williamson. In Illinois, *S. megalocarpus* occurs on 23 species in 18 host genera. Fresh host material collected in the field and appearing uninfected can develop *S. megalocarpus* colonies after incubation in the laboratory. The ability of *S. megalocarpus* to colonize previously uninfected hosts was demonstrated by inoculation studies in the laboratory. Because the known distribution of potential hosts in Illinois is much broader than documented here, further attention to *S. megalocarpus* should more fully elucidate the host and geographic ranges of this Zygomycete in the state. Using light and scanning electron microscopy, the heretofore unmeasured warts on the zygosporangium were 4-6 μm broad and 5-8 μm high, providing additional information for circumscription of this genus.

INTRODUCTION

Syzygites (Mucorales, Zygomycetes) is a presumptive mycoparasite that occurs on fleshy fungi (Figs. 1-2) and contains a single species, *S. megalocarpus* Ehrenb.: Fr. (Hesseltine 1957). It is homothallic and forms erect sporangiophores which are dichotomously branched and bear columellate, multispored sporangia at their apices (Fries 1832, Hesseltine 1957, Benny and O'Donnell 1978, O'Donnell 1979). *Syzygites* has been isolated and grown in pure culture (Hesseltine 1957, Poff 1965, Jong and Gantt 1984).

Information on the host range of *Syzygites* is scant and fragmentary, and, with exception of a brief mention in a previously published abstract (Kovacs and Sundberg 1994), no literature exists on the occurrence of this genus in Illinois. Therefore, the general objectives of this study were to document the features and range of *Syzygites* in the state.

MATERIALS AND METHODS

Infected fleshy fungi (e.g., basidiomata) were gathered in southern Illinois in a variety of habitats from May to December in 1993 and 1994 and sporadically thereafter. Some specimens were photographed. All were then either air dried or dried via convection current and deposited as permanent voucher specimens in the Mycological Collections of Southern Illinois University Herbarium (SIU).

Field collected host specimens, which appeared parasite free, sometimes developed visible parasite colony growth when stored in a refrigerator or cold room for several days. Therefore, host material that appeared parasite free was also collected, wrapped in clean wax paper, wax paper bags, and/or brown paper bags, and stored at room temperature or in a cold room or refrigerator at 5-10°C. These collections were checked weekly, for up to four weeks, for growth of the parasite.

To test for the potential of *S. megalocarpus* to grow on other selected fleshy fungi, inoculations were conducted in the laboratory by placing hyphae from an actively growing culture of *S. megalocarpus* directly on the pileus, lamellae, stipe, or peridium of possible host fungi. Cultures used were NRRL 6288 (from the United States Department of Agriculture Research Laboratories, Peoria, Illinois) and/or WC-94 isolated from a collection (Sundberg 94-V-1) of *S. megalocarpus* on *Boletinellus merulioides* (Schw.) Murr. made in Williamson County, Illinois in May, 1994. Both were maintained on corn meal plus agar (CM+; Wicklow and Sundberg 1976). Inoculated specimens were incubated at room temperature in ambient light in clean glass or plastic containers, loosely sealed to maintain humidity, and examined daily for evidence of growth.

To enhance completeness of the study, herbarium specimens of *Syzygites megalocarpus* (and/or its synonyms) were also requested on loan from 21 institutions within the United States.

A composite description of *S. megalocarpus* was complied and host identifications were made from data obtained from personal fresh collections, herbarium specimens collected by others, and cultures of the two isolates noted above. Macro- and micro-morphological features of *S. megalocarpus* and its hosts were described using standard procedures (e.g., Smith 1949, Largent 1977, Largent et al. 1977). Ten or more measurements were made for each fungal structure unless limited by the amount of material in the collection. The term zygosporangium was used to denote the structure that develops and is held in place between the suspensors (Alexopoulos et al. 1996). To supplement micro-morphological observations, scanning electron microscopy (SEM) was used following the standard preparation methods described in Postek et al. (1980). When possible, hosts were identified to species.

A host list for *Syzygites megalocarpus* was prepared from available data. Abbreviations for herbaria with collections noted herein are according to Holmgren et al. (1990).

RESULTS

Syzygites megalocarpus Ehrenb.: Fr. Systema Mycologicum 3: 329, 1832.

Sporangiophores (Fig. 3) 0.5-40 mm high, erect, up to 6 times dichotomously branched, septate, striate or rough at least on the lower part, hyaline to pale brown, and with terminal sporangia. Sporangia 50-150 µm broad, globose to irregularly globose, thin-walled, and yellow (gray in reflected light). Columella (Fig. 3) present, 30-100 µm broad, subglobose to irregularly globose. Sporangiospores (Figs. 3-4) 5-35 µm broad, globose to irregularly globose to ovoid, surface verrucose, hyaline to pale brown. Homothallic. Zygosporangia 160-375 µm in diam, pallid at first, but turning dark brown to black when mature, globose to irregularly globose, surface developing short, stout warts that are blunt and somewhat flattened at the apex. Warts (Fig. 6) 4-6 µm broad and 5-8 µm high when viewed and measured with SEM. Suspensors (Fig. 5) lateral, nearly globose to ovoid except where attached to the zygosporangium and supporting hyphae. Hyphae 3-60 µm broad, non-septate except near reproductive structures, hyphal surface striate or rough.

Habit and Habitat: Colonies single to scattered (Fig. 1) on various fleshy fungi (Table I). In lawns, wetland areas, and a variety of woodland habitats. May through October.

Specimens examined: Cook Co.: F 523958, River Forest, Oct. 1898, (F). Gallatin Co.: Methven 8019, Rim Rock Trail, Pounds Hollow Recreation Area, Oct. 15, 1994, (EIU). Jackson Co.: ILLS 38157, Turkey Bayou, Sept. 27 1978, (ILLS); Akers 93/10-03/002, Trail of Tears State Forest, Oct. 8, 1993, (SIU); Sundberg s. n., developed in laboratory, summer 1993, (SIU); Kovacs IX-M-94-M, Carbondale, Sept. 1994, (SIU); Kovacs V-25-94-1, Giant City State Park, May 25, 1994, (SIU); Kovacs V-94-2, Giant City State Park, May 1994, (SIU); Kovacs VI-94-A, Giant City State Park, June 1994, (SIU); Kovacs I-V-94-11, laboratory inoculated, June 1994, (SIU); Kovacs C-95-3, dried culture of NRRL-6288 on CM+, 1995, (SIU); Kovacs C-95-4, dried culture of WC-94 on CM+, 1995, (SIU); Kovacs C-94-2, dried culture of WC-94 on host and CM+, 1995, (SIU); Kovacs I-94-4, laboratory inoculated, 1994, (SIU); Kovacs I-94-2a, laboratory inoculated, Oct. 1994, (SIU); Kovacs I-94-2b, laboratory inoculated, Oct. 1994, (SIU); Kovacs I-94-3a, laboratory inoculated, Oct. 1994, (SIU); Kovacs I-94-3b, laboratory inoculated, Oct. 1994, (SIU); Kovacs I-IV-95-1, laboratory inoculated, April 1995, (SIU); Kovacs I-94-1, laboratory inoculated, Oct. 1994, (SIU); Kovacs I-95-1a, laboratory inoculated, 1995, (SIU); Kovacs I-95-2a, laboratory inoculated, 1995, (SIU); Kovacs C-94-1, dried culture with host on CM+, June 1994, (SIU); Bray 23, DeSoto City State Park, Oct. 24, 1995, (SIU); Overton 960731.1, Murphysboro, Jul. 1996, (SIU). Union Co.: Kovacs VI-94-1, Trail of Tears State Forest, June 1994, (SIU); Kovacs VI-94-2, Trail of Tears State Forest, June 1994, (SIU); Kovacs VI-94-3, Trail of Tears State Forest, June 1994, (SIU); Kovacs VI-94-4, Trail of Tears State Forest, June 1994, (SIU); Kovacs VI-94-5, Trail of Tears State Forest, June 1994, (SIU); Kovacs VI-94-7, Trail of Tears State Forest, June 1994, (SIU); Sundberg 98-X-23-1, Carbondale, October 23,1998 (SIU). Williamson Co.: Sundberg 94-V-1-1 Crab Orchard Lake area, May 1, 1994 (SIU)--culture WC-94 isolated from this collection.

Host List

Table 1 provides a complete list of presently known mycohosts for *Syzygites megalocarpus* in Illinois. Although institutions throughout the United States were contacted, specimens of *S. megalocarpus* from Illinois were found only in the holdings of Illinois herbaria. Of the 33 voucher collections of *Syzygites* from Illinois, two genera (*Pluteus* and *Tylopilus*) were noted earlier as new hosts (Kovacs and Sundberg 1994) and five genera--*Boletinellus*, *Ganoderma*, *Morchella*, *Omphalotus*, and *Tricholoma*--and 15 host species are reported herein as new host records in the United States.

Five species--*Agaricus bisporus* (Lange) Sing., *Agaricus campestris* L.: Fr., *Calvatia cyathiformis* (Bosc.) Morg., *Ganoderma lucidum* (Curt.: Fr.) Karst., and *Morchella esculenta* (L.) Pers.--are currently known as hosts for *Syzygites* only from laboratory inoculations.

DISCUSSION

Macro- and micro-morphological data collected on *S. megalocarpus*, although somewhat variable, agree with previously published descriptions (e.g., Fries 1832, Hesseltine 1957, Benny and O'Donnell 1978, O'Donnell 1979). In earlier descriptions, the warts on the surface of the zygosporangium (Fig. 6) were described as blunt in appearance, but measurements were lacking. Use of light and scanning electron microscopy demonstrated that these blunt warts are 4-6 µm broad and 5-8 µm high.

Syzygites megalocarpus is known to occur in the United States on at least 65 host genera in 22 families of Basidiomycetes as well as few Ascomycetes in the Pezizales and Helotiales (Kovacs 1995). However, in Illinois, *S. megalocarpus* has been found on only 18 genera in 11 families (see Table I). Given the broad distribution in Illinois of fleshy fungi recorded as hosts of *S. megalocarpus* from elsewhere in the country, it seems reasonable to assume that *S. megalocarpus* should be more widely distributed in the state and on more hosts than current records indicate.

Ingold (1953) states that *Syzygites* occurs on agarics in the fall, however, our data indicate a longer potential growth period--from May through October. The temperature range for vegetative growth of *Syzygites* is is 5-30°C (Baker 1931, Wenger and Lilly 1966), suggesting the potential for growth during much of the year (assuming no other limiting factors). Sporangiospores of *Syzygites* can survive freezing (Goos et al. 1967), apparently can survive throughout the winter months, and may be a source of inoculum for new infections the following season. Alternatively, zygospores readily germinate (Gauger 1978) and, thus, may perform this function.

SUMMARY

Syzygites megalocarpus occurs in Illinois on 18 different host genera and 23 host species of fleshy fungi (including seven species in six genera which were laboratory inoculated during this study). *Syzygites* was collected on hosts from a variety of habitats from May through October in five counties--Cook, Gallatin, Jackson, Union, and Williamson. Since potential hosts for *S. megalocarpus* occur throughout Illinois, more attention to specimen collecting would undoubtedly add to its known host list and geographic range

within the state. Warts on the surface of its zygosporangia are noted herein as short, stout projections that are blunt, somewhat flattened at the apex, and 4-6 μm broad x 5-8 μm high.

ACKNOWLEDGMENTS

Appreciation is given to A. E. Liberta of Illinois State University (ISU), P. D. Sørensen of Northern Illinois University (DEK), and R. V. Gessner of Western Illinois University (MWI) for supplying information regarding their respective herbarium holdings. We gratefully acknowledge S. Long and G. M. Mueller of The Field Museum of Natural History, Chicago (F), A. Methven of Eastern Illinois University (EIU), and J. L. Crane of The Illinois Natural History Survey (ILLS) for allowing use of specimens in their care. We thank K. O'Donnell and S. W. Peterson of the United States Department of Agriculture, National Regional Research Laboratories (NRRL) for providing a culture of *Syzygites megalocarpus*. Finally, appreciate the careful and critical reviews offered by A. Methven (Eastern Illinois University), and two unidentified reviewers.

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Table 1. Host list for *Syzygites megalocarpus* occurring in Illinois.

Host Higher Taxa	Host[1,2]	Voucher Specimen Location[3]
ASCOMYCETES:		
"Discomycetes"		
Pezizales		
Morchellaceae:	*Morchella esculenta* (L.) Pers.[5]	SIU[4]
BASIDIOMYCETES:		
"Hymenomycetes"		
Aphyllophorales		
Ganodermataceae:	*Ganoderma lucidum* (Curt.: Fr.) Karst.[5]	SIU
Agaricales		
Agaricaceae:	*Agaricus bisporus* (Lange) Sing.[5,6]	SIU
	Agaricus campestris L.: Fr.[5]	SIU
	Agaricus subrufescens Pk.	SIU
Amanitaceae:	*Amanita thiersii* Bas	SIU
Boletaceae:	*Boletus affinis* Pk.	ILLS
	Boletus ornatipes Pk.[4]	SIU
	Boletus sp.[4]	SIU
	Boletinellus merulioides (Schw.) Murr.[4]	SIU
	Suillus americanus (Pk.) Snell[5]	SIU
	Tylopilus sp.[4]	SIU
Coprinaceae:	*Psathyrella* sp.	F
Cortinariaceae:	*Cortinarius* sp.[4]	SIU
Pluteaceae:	*Pluteus cervinus* (Schaef.: Fr.) Kumm.	SIU
Russulaceae:	*Lactarius piperatus* (Fr.) Gray	SIU
	Russula sp.[4]	SIU
Tricholomataceae:	*Lentinus edodes* (Berk.) Sing.[5,6]	SIU
	Omphalotus olearius (DC.: Fr.) Sing.	SIU
	Tricholoma resplendens (Fr.) Quét .	SIU
	Tricholoma sp.	SIU
"Gasteromycetes"		
Lycoperdales		
Lycoperdaceae:	*Calvatia cyathiformis* (Bosc.) Morg.[5]	SIU
	Lycoperdon pyriforme Pers.	EIU

[1] Underline = new host record for the United States.
[2] sp. or spp. = species not determined.
[3] Herbarium abbreviation = specimen examined; herbarium abbreviations from Holmgren et al. (1990).
[4] Field collected host material which developed infection after incubation in the laboratory.
[5] Laboratory inoculation of host with *Syzygites megalocarpus.*
[6] Host obtained from local grocery store.

Figures 1-2. *Syzygites megalocarpus* on two inoculated fleshy fungi. 1. On *Calvatia cyathiformis*. 3/4x. 2. On *Morchella esculenta*. 1x.

Figures 3-6. Scanning electron micrographs showing some features of *Syzygites megalocarpus*. 3. Sporangiophores displaying typical dichotomous branching. S = sporangiospore, C = columella. (ca. 1,200x). 4. Sporangiospores showing surface decorations. S = sporangiospore. (ca. 12,300x). 5. Young zygosporangium with suspensors. Z = zygosporangium, Su = suspensor. (ca. 1,200x). 6. Surface of more mature zygosporangium showing blunt warts. W = wart. (ca. 6,100x).

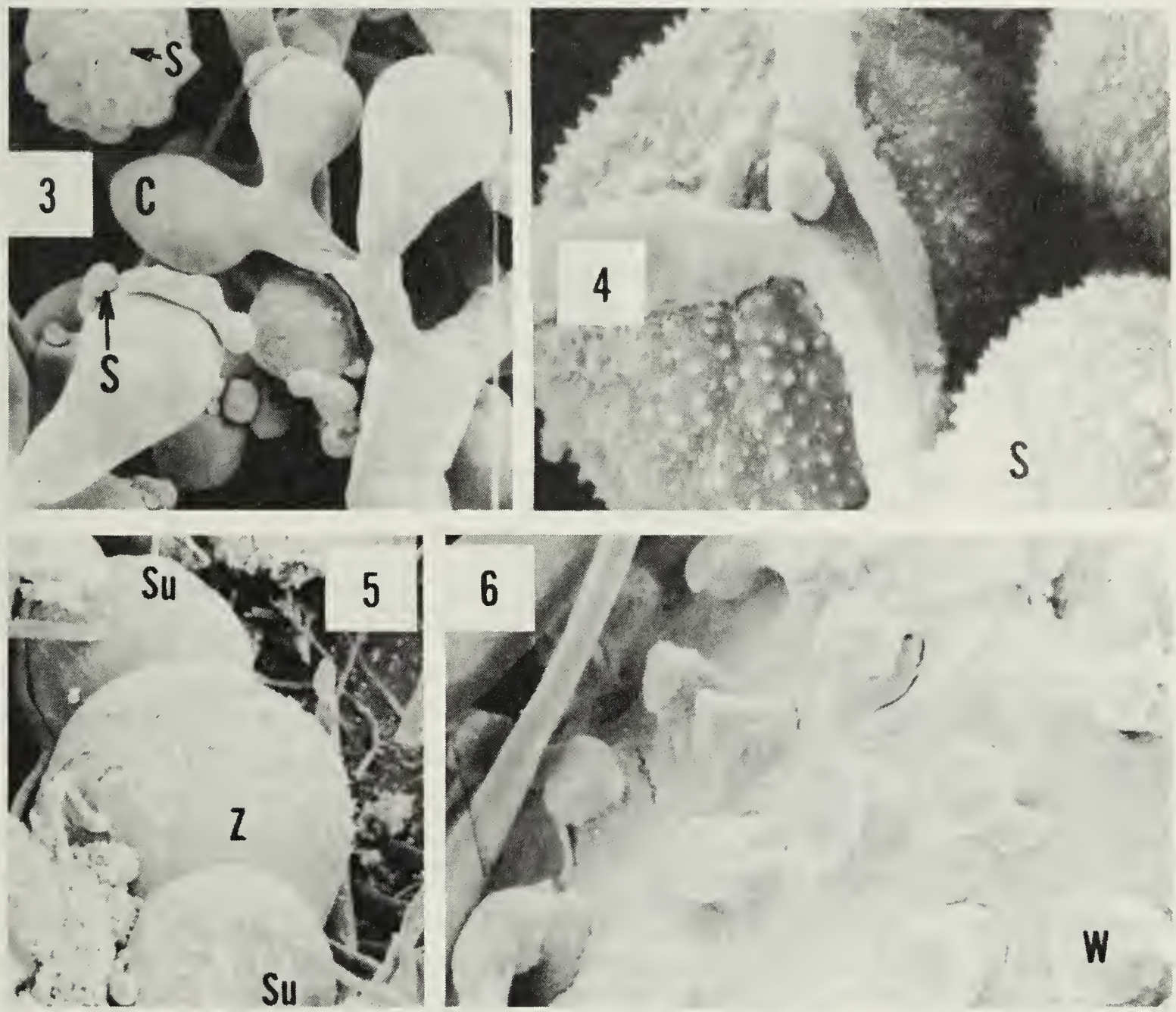

Figure 7. Voucher specimen supported distribution of *Syzygites megalocarpus* in Illinois.

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 191-202

received 7/28/98
accepted 1/6/99

Translocation of Carbon-14 in *Pinus ponderosa* Seedlings Subjected to Long-term Sulfur Dioxide and Water Stress

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ABSTRACT

The Rocky Mountain variety of ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm) was grown for two years in cylindrical plastic covered open-top chambers (3 m diameter by 3 m height) in an outdoor environment. Tree seedlings were subjected to three concentrations of SO_2 and three levels of water stress. The levels of SO_2 were annual hourly means of 0, 27, and 54 $nL \cdot L^{-1}$. The levels of water stress were based on soil water content, and were leaf water potentials of 0.1, 0.3 and 0.6 Mpa. After 10 months of treatment, seedlings were exposed to $^{14}CO_2$ to determine how stress altered the translocation of carbon. The effects of SO_2 and water stress were similar, with both reducing the total amount of available carbon translocated to roots. Unstressed seedlings exported more assimilate to roots and retained less assimilate in needle tissue as compared to any combination of SO_2 and water stress. When water stress was applied, there was no difference in the quantity of assimilate translocated to roots at any of the SO_2 levels. Therefore, the effects of SO_2 and water stress were not additive.

Key Words. SO_2, water stress, translocation, $^{14}CO_2$

INTRODUCTION

Since the start of the industrial revolution, air pollution has continually impacted vegetation. Due to the burning of fossil fuels and biomass, and smelting processes, global emissions of sulfur dioxide have risen steadily, surpassing natural sources (87 TgS and 60 TgS for anthropogenic and natural sources, respectively; Houghton et al. 1990). These emissions will not only influence climate change through the formation of aerosols, but will also have a direct effect on vegetation (Krupa 1997).

"Plant productivity is determined by a complex series of events leading from CO_2 fixation in the chloroplasts, formation of phloem-mobile and storage metabolites, and delivery of these to sink tissues. We are only just beginning to understand the extent of these complexities" (Madores and Lucas 1995). This partitioning of carbon determines plant health and vigor under nearly all conditions. The regulation of partitioning during times of stress imparts resilience to the plant, and subsequently leads to good or bad harvests. The damaging stresses of air pollution to vegetation are well-known, and nowhere is plant carbon allocation more important than in partitioning during times of stress.

Carbon translocation and stress have been studied over the last three decades for several groups of species including crops and natural grasses (Jones and Mansfield 1982a, Major et al. 1978, Shih et al. 1983), broad-leaved tree species (Dickson and Larson 1981, McLaughlin et al. 1979), and conifer species (McLaughlin et al. 1982, Schier 1970, Webb 1977). Amount of assimilate translocated in these studies varied widely, from as low as 0.1 to 5% translocated from labeled leaves/stems to nonlabeled leaves/stems (Jones and Mansfield 1982a) to as high as 45% (McLaughlin et al. 1979). However, the results from McLaughlin et al. (1979) may not reflect the actual assimilate translocated, since assimilate in the initially labeled branch was included. This assimilate remaining in the initially labeled leaf can be quite high. Based on measured respiration values and measured retention of assimilates, McLaughlin et al. (1979) estimated that the amount of $^{14}CO_2$ translocated from the labeled leaves ranged from 0% to 60%. So, it is unlikely that the 45% of assimilates found in all leaves was due to an appreciable amount in nonlabeled leaves.

Several studies have reported alterations in biomass and partitioning due to air pollutant injury (He et al. 1996, Heagle et al. 1979, Hogsett et al. 1985, Leininger et al. 1991, McBride et al. 1975, Norby and Kozlowski 1981, Vins and Mrkva 1973). Studies of pollutant effects on allocation patterns using $^{14}CO_2$ tracing are rare and for some pollutants, dated. For example, one of the most current studies of the effects of SO_2 on tree species was conducted 16 years ago by Jones and Mansfield (1982a) where they investigated the responses of translocation of $^{14}CO_2$ to SO_2 exposure in *Phleum pratense*. They showed assimilate translocated to roots to be reduced by SO_2, which could lead to a reduced root/shoot ratio. Thus, altered biomass allocation induced by SO_2 can at least in part, result from decreased transport to the root system.

Other work has emphasized the importance of seasonal patterns in the flow and partitioning of assimilate (McLaughlin et al. 1979, Schier 1970, Webb 1977). White pine showed an increase in needle retention of photosynthate (McLaughlin et al. 1982). McLaughlin et al. (1982) concluded that decline of white pine in East Tennessee was attributable to stress brought on by oxidant injury. An increase in needle senescence was noted. Reduced carbon storage capacity was observed in the fall with a resulting shortage in carbon for new foliage formation in the spring. New needle growth was more self-reliant for its carbon supply and was shorter, which resulted in lower gross photosynthetic production and a higher retention of photosynthate.

With increasing concerns about the implications of climate change, there is a need to investigate the impacts of SO_2 in relation to its interactions with environmental parame-

ters, such as water availability, that may change under future climate scenarios. No studies to date have shown how water stress and SO_2 may interact and influence translocation patterns in conifers. Thus, one purpose of our study of SO_2 and water stress was to determine whether *Pinus ponderosa* would show a reduced storage capacity that would result in a carbon shortage the following spring. This long-term study would further show if a specific tissue organ was being preferentially affected by SO_2. Finally, this study would assess the possible interaction between water stress and SO_2 on the translocation of carbon.

MATERIALS AND METHODS

Plant Material

Seedlings of the Rocky Mountain variety of *Pinus ponderosa* var. *scopulorum* Engelm were obtained from the Colorado State Nursery in Fort Collins, Co. The seedlings were 2-year-old container stock with roots in 5 x 5-cm plugs. The seed source was the San Isabel National Forest near the town of Rye, Co. (38% latitude, 105% longitude).

The seedlings were transplanted into in 15-cm aluminum foil covered plastic pots. The potting mix contained equal parts of clay (Cohasset Series), redwood compost, Monterey #4 sand, and perlite (Jenkinson 1980).

Sulfur Dioxide Exposure

The seedlings were grown throughout the experiment in open-top chambers (Heagle et al. 1973, Rogers et al. 1983) at Lawrence Livermore National Laboratory. The air entering the open-top chambers was carbon-filtered prior to addition of SO_2.

A sampling line was centrally located in each chamber to monitor the level of SO_2. Chambers were monitored with a data acquisition system and TECO SO_2 analyzers (TECO, Hopkinton, Mass.) to maintain levels of SO_2 of 0 $nL \cdot L^{-1}$, 27 $nL \cdot L^{-1}$, and 54 $nL \cdot L^{-1}$ annual hourly means. These hourly mean concentrations are similar to those used by Pell et al. (1988). The high SO_2 treatment (annual hourly mean of 54 $nL \cdot L^{-1}$) represented a worse case scenario in the western United States for exposures near metal smelters (Hogsett et al. 1989, Leininger et al. 1991) and represent peak concentrations for moderately polluted areas (Krupa 1997). Data collection was continuous during hours of fumigation with updates every 15 minutes over the entire 26-month experiment. This resulted in SO_2 concentrations being controlled at ±10% of the desired levels. The Teflon sampling tubes were heated and insulated to prevent condensation.

Water Stress Treatments

Three levels of water stress were implemented concurrently with SO_2 exposure. Leaf water potential was not continually determined since this would have led to excessive tissue destruction. Instead, leaf water potential was determined periodically to establish the level of water stress induced by predetermined levels of water loss from the pot and plant. Seedlings grown under no water stress were maintained by watering after a loss of 30 g $H_2O \cdot L$ $soil^{-1}$ (leaf water potential of 0.1 MPa). Seedlings grown under low water stress were watered after a loss of 70 g $H_2O \cdot L$ $soil^{-1}$ (leaf water potential of 0.3 Mpa) and those grown under high water stress at a loss of 110 g $H_2O \cdot L$ $soil^{-1}$ (leaf water potential of 0.6 MPa). It was found that, due to the homogeneous potting medium used, as well as

the large amount of soil compared to seedling size, there was little variation among plants in the amount of the water drawdown within a particular water treatment level.

To assure complete and uniform drainage, metal-support grids were placed under pots. In addition, rain covers were placed above chambers so that all added water was controlled.

Translocation Analysis

In November, after 11 months of SO_2 fumigation and water stress, seedlings from each of the nine treatment combinations were selected to determine the effects of stress on the translocation of photosynthetically fixed ^{14}C. Each seedling was placed in a translocation device to receive a pulse of ^{14}C as $^{14}CO_2$ (Figure 1). The method for exposing tissue to $^{14}CO_2$ and tracing the isotope through the plant over the course of one week was similar to McLaughlin et al. (1982). A preliminary experiment had shown that in *P. ponderosa* a daylight exposure of 5 minutes ensured that sufficient ^{14}C would reach the roots. This preliminary study revealed the importance of a sampling scheme that considered age class, needle location, and tissue type. We also found that the effect of needle location within an age class could be accounted for by sampling tissue at set intervals along the stem.

The exposures to $^{14}CO_2$ were made during mid-day, with ambient light levels when uptake would be highest. The translocation chamber was completely filled with $^{14}CO_2$ using a 2 $L \cdot min^{-1}$ flow rate over a 5-minute period. This flushed the entire chamber volume every 5 minute.

The translocation device was first opened, the internal fan was turned on, and the seedling placed into the device so all of the foliage was enclosed. The seedling was secured to the bottom plastic bag of the translocation device by using a rubber gasket to form a collar around the base of the seedling and then securing the bag to the gasket with a cable tie. After closing the device, the seedling was exposed to $^{14}CO_2$ gas for 5 min at 2 $L \cdot min^{-1}$ and then removed immediately.

Seven days after exposure, all plants were harvested, separated by tissue type, and analyzed for ^{14}C. Needle tissue was sampled from each age class by removing a fascicle every 5 cm along the stem. This technique increased the accuracy of determining total $^{14}CO_2$ uptake. After the tissue was collected, it was ground and separated into three subsamples. Subsamples were then wrapped in ashless filter paper and combusted in a Packard B306 Tri-Carb Sample Oxidizer (Packard Instruments, IL). The ^{14}C from the combusted subsample was captured in a Carbosorb E solution and mixed with a standard fluor (Permafluor E; Packard Instruments, IL). The resulting solution was then placed in a Packard Tri-Carb 4530 Liquid Scintillation Counter (Packard Instruments, IL) and counts per minute (CPM) of ^{14}C were obtained. Before and after every 25 samples, a ^{14}C standard and background blanks were run through the entire combustion and counting process. This enabled us to determine the counting efficiency of our processes, and convert CPM into disintegration per minute (DPM), and finally converted into Becquerels (Bq). Houpis (1989) provides a detailed description of the entire process.

The amount of ^{14}C translocated to a particular tissue type was calculated from the following equation:

$$Bq_t = (Bq / wt) * W ,$$

where

Bq_t = Bq found in a tissue type (needles and stems by age class, and buds and roots),
wt = weight of the subsample , and
W = total weight of the tissue type.

Experimental Design

This study was part of a larger study that lasted more than two years and was a completely randomized 3 x 3 factorial design. The larger study had two main factors, SO_2 and water stress. Three levels of each factor were studied; annual hourly means of 0 (no SO_2), 27, and 54 $nL \cdot L^{-1}$ SO_2; and no, low, and high water stress. Three seedlings (replicates) were randomly taken from each of the nine treatments. An ANOVA was used to determine differences in biomass and translocated ^{14}C in each of the tissue types (needles, stems, buds, and roots). Needle and stem tissue were also analyzed by age class using a three-factor ANOVA (with SO_2, water stress, and age class as factors).

The number of samples required in each of the studies was determined by both a power test and logistic considerations. If differences existed, then Newman-Keuls Pairwise Comparisons were used (Neter and Wasserman 1985). For all comparisons, a $p<0.1$ (selected a priori) was used to determine significance. In all figures, mean values having the same lower case letter are not significantly different, as determined by Newman-Keuls Pairwise Comparisons.

RESULTS

Sulfur dioxide did not significantly affect the percentage of Bq found in any of the age classes of needles, or in any of the older age classes of stems. However, the buds and the youngest stem tissue had a significantly higher percentage of translocated carbon at 54 $nL \cdot L^{-1}$ SO_2. In contrast, the control treatment had significantly more carbon translocated to root tissue. Perhaps the most important finding (Figure 2) was that seedlings in the control treatment (no SO_2) had less carbon allocated to the top of the plant, with more carbon exported to roots, than did the seedlings in the treatments with SO_2.

Although the water stress effect was not entirely similar to that for SO_2, some of the trends in the allocation of translocated carbon were comparable. These included less carbon in the leaf tissue of the control seedlings, little or no difference among older age classes of stems, and the control seedlings having the greatest amount of carbon translocated to roots (Figure 3). However, the relative amount of translocated carbon found in the upper stem classes of control plants (no SO_2) was the opposite of that found in seedlings receiving SO_2. In the case of water stress, significantly more carbon was found in the youngest stem age classes of the seedlings in the control treatment than was found in seedlings in the high water stress treatment. Comparison of seedlings with and without water stress suggested that the increase in carbon translocated to roots and to the 0-year-old age class of stems (i.e., stem tissue associated with current age class of needles) was offset by a small increase in carbon translocated to the other tissue types at high water stress. A significantly higher quantity of carbon was found in the 0-year-old age class of

needles (i.e., current age class of needles) in the low water stress treatment (Figure 3), which was due to a significant interaction with SO_2.

The SO_2 x water stress interaction significantly affected the quantity of carbon translocated to the 0-year-old age class of needles, the 0- and 1-year-old age class of stems, and the roots (Figures 4a-c). The interactions for the 0-year-old age class of stems indicate that as SO_2 level increased, the amount of translocated carbon found in the 0-year-old age class of stems in the no water stress treatment increased compared to other water stress treatments. Another notable trend was that control seedlings (no SO_2 and no water-stress) had the lowest translocation to 0- year-old age class of needles compared to all other treatments. Also, the seedlings in the no SO_2 and no water stress treatment had the greatest amount of labeled carbon found in their roots. Levels of translocated carbon from all other treatment combinations were not significantly different. This indicates that, when comparing any stress combination, the control group exported significantly more carbon from the 0-year-old needles to the roots. Once the plants experienced stress, there was a significant decrease in carbon moving to roots.

DISCUSSION

It is well known that climate interacts with air pollution, and together they determine the plant's response to air pollution (Tingey and Olszyk 1985). Due to the influence of water availability on stomatal conductance, it would be expected that water stress would affect a plant's uptake of SO_2 through the stomates. In addition, SO_2 will influence the distribution of assimilate (Murray 1985, Gould and Mansfield 1988, and Murray and Wilson 1990). Our study demonstrated that the effects of SO_2 and water stress were similar to previous studies, with our results showing a reduction in assimilate translocation to roots. The SO_2 effect resulted in a higher retention of assimilates in needle tissue. This supports conclusions for *Pseudotsuga menziesii* (Leininger et al. 1991), *Phleum pratense* (Jones and Mansfield 1982a, 1982b, and Mansfield and Jones 1985) and *Pinus strobus* (McLaughlin et al. 1982). However, the difference in the amount of assimilate found in root tissue due to water stress was the result of higher retention of assimilate in stem tissue.

In our study, seedlings not stressed due to ample water and no SO_2 exposure exported more assimilate to roots at the expense of assimilate retention within needle tissue. All other combinations of SO_2 and water stress resulted in a significant reduction in translocation to roots. These findings are supported by reports that SO_2 not only reduces the production of assimilates (Strand 1995), but also inhibits their transport (Fialho and Bucker 1996, Gould and Mansfield 1988, McLaughlin et al. 1982, Murray and Wilson 1990, Noyes 1980) and sulfate transport (Herschbach et al. 1995). Reduced transport resulted in a decreased translocation to the root system and increased retention in leaves (Gould and Mansfield 1988 with *Triticum aestivum*, Jones and Mansfield 1982a with *Phleum pratense*, Lorenc-Plucinska 1986 with *Pinus sylvestris*). This pattern of increased retention of assimilates in needle tissue due to SO_2 stress is most likely a function of an increased need of assimilates for repair and maintenance in the damaged tissue (Wilson 1995, Wulff and Karenlampi 1996), detoxification mechanisms (Saraswathi and Madhava Rao 1995, Slovik 1996), or chemical defense mechanisms (Julkunen-Tiitto et al. 1995). Increased foliar retention means less assimilates translocated to roots, which

can reduce stored carbon available for growth in the following year. Thus, the observed suppression of growth by SO_2 (Houpis 1989) could be attributed to reduced photosynthesis, an increase in assimilates needed for repair and maintenance, and less carbon storage (Fialho and Baker 1996).

The interaction between increasing water stress and SO_2 is especially important since both stresses are common, and water stress may increase under certain future climate change scenarios (Pastor and Post 1988). Once water stress was applied, there was no significant difference in assimilates translocated to roots at any of the SO_2 levels. Jones and Mansfield (1982a) showed that increasing SO_2 concentration resulted in a significant reduction in the amount of assimilate translocated to roots. They hypothesized that SO_2 could exacerbate the effect of water stress. However, our results do not confirm this hypothesis because the plants subjected to both levels of water stress showed no alteration in their pattern of translocation to roots when exposed to SO_2. Thus, as suggested by Wilson (1995), exacerbation of water stress effects by SO_2 would not be expected, and plants growing in present or future drier habitats are less likely to exhibit SO_2- induced changes in allocation patterns as would be expected in more mesic habitats.

ACKNOWLEDGMENTS

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-Eng-48.

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Figure 1. Diagram of translocation device: Top view (1a) and Side view (1b).

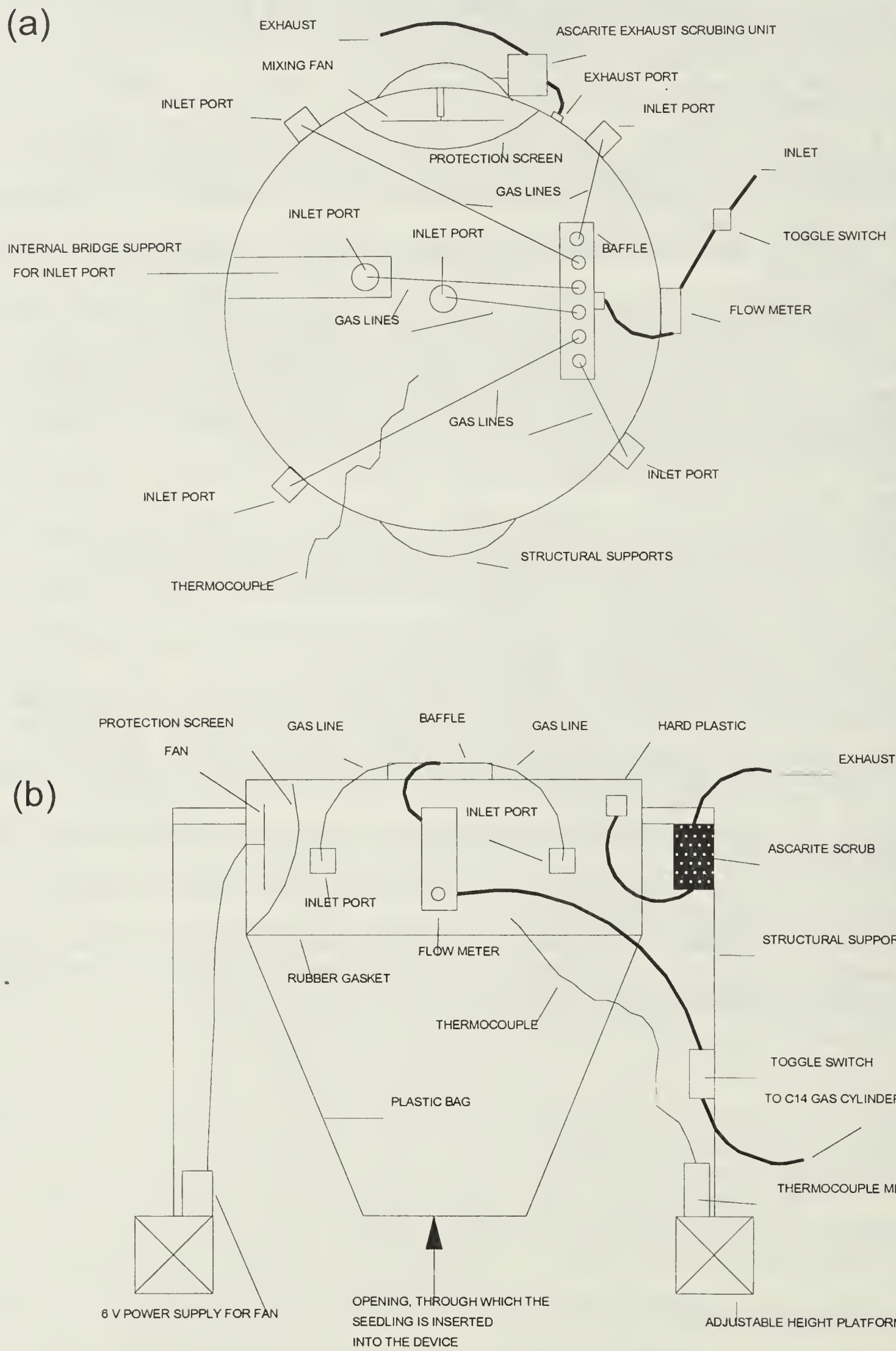

Figure 2. Percent of Bq found seven days after the initial pulse of $^{14}CO_2$ in the various tissue types for seedlings grown under increasing SO_2 concentrations. (LFx = leaf tissue, BDS = bud tissue, STx = stem tissue, RTS = root tissue; where x indicates the age (years) of the tissue.) Letters indicate statistical groupings for those tissue types that have significant difference, and statistical comparisons are made only within a particular tissue type as determined by the multiple comparison tests.

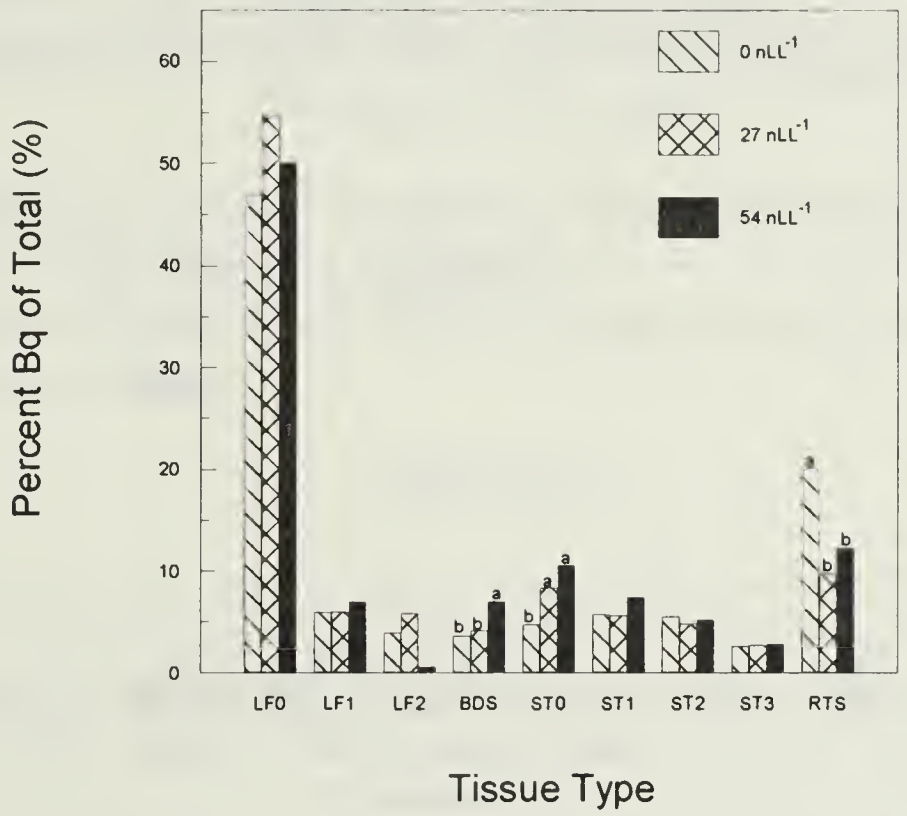

Figure 3. Percent of Bq found seven days after the initial pulse of $^{14}CO_2$ in the various tissue types for seedlings grown under increasing water stress. (LFx = leaf tissue, BDS = bud tissue, STx = stem tissue, RTS = root tissue; where x indicates the age (years) of the tissue.) Letters indicate statistical groupings for those tissue types that have significant difference, and statistical comparisons are made only within a particular tissue type as determined by the multiple comparison tests.

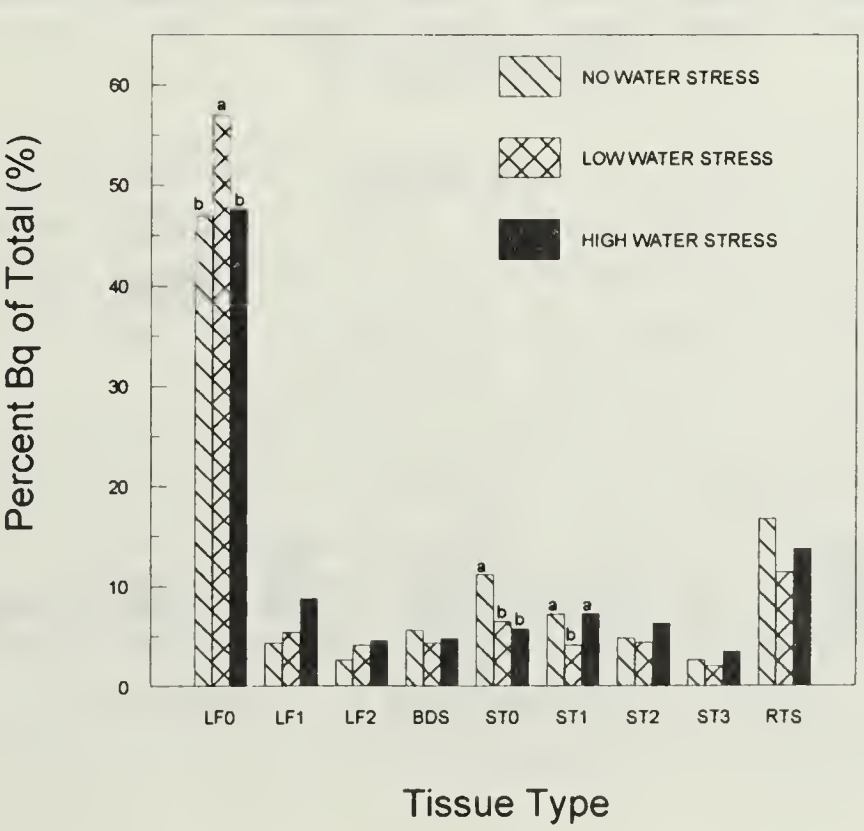

Figure 4. Percent of Bq found seven days after the initial pulse of $^{14}CO_2$ in the various tissue types for seedlings grown under increasing water stress; at 0 $nL \cdot L^{-1}$ SO_2 (4a), 27 $nL \cdot L^{-1}$ SO_2 (4b), and 54 $nL \cdot L^{-1}$ SO_2 (4c). (LFx = leaf tissue, BDS = bud tissue, STx = stem tissue, RTS = root tissue; where x indicates the age (years) of the tissue.) Pairwise comparisons for each tissue type were made between each of the nine treatments Letters indicate statistical groupings for those tissue types that have significant difference, and statistical comparisons are made only within a particular tissue type as determined by the multiple comparison tests.

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 203-209

received 6/3/98
accepted 12/16/98

Effects of Exercise Detraining on Lipid Storage in Rats

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ABSTRACT

This study was done to determine if regular exercise followed by detraining would result in an elevation of lipids in serum and body tissue. The regular exercised (RE) rat group trained by swimming for 70 minutes four times per week for the entire 21 weeks of the exercise protocol. The detrained (DE) group trained with equal duration of exercise for 16 weeks, then did not swim for the remaining five weeks to detrain and the control (CO) group did not exercise. At the end of the study, no significant differences were found among the three groups for serum TC, HDL-C, and TG. However, significant differences were observed in body weight gained and in skin lipid. The trained group had the least amount of stored fat in the form of triglyceride (4.9%) and the control group had the most (10.2%). These findings suggest that cessation of training (detraining) reverses the effects of exercise on lipids stored in tissues.

Key words: exercise, detraining, lipids, rats

INTRODUCTION

Coronary heart disease (CHD) is the chief cause of death in the United States killing more Americans than all forms of cancer combined (1,2). The cause of CHD has been strongly correlated to an atherogenic life-style which can be characterized by a diet excessive in saturated fat, calories and salt, unrestrained weight gain, and a sedentary existence. The risk of developing CHD has been shown to be approximately twice as likely in sedentary people as those who were vigorously active (3). Unrestrained weight gain tends to exacerbate all these atherogenic factors predisposing one to blood vessel blockage (4). In the Framingham heart study, the rates of CHD after 14 years of follow-up were inversely related to physical activity in men but not women. This relation was independent of age, blood pressure, smoking, and cholesterol level (3). Results of numerous clinical investigations show that management of blood lipids and lipoproteins through regular, aerobic exercise significantly benefits cardiovascular health. For exam-

ple, Superko (5) showed that regular exercise decreases total cholesterol (TC) and triglyceride (TG) levels while increasing levels of high-density lipoprotein cholesterol (HDL-C) in humans. Additional potential benefits from physical activity involve helping to maintain body weight, acting as a substitute for smoking, improving glucose-insulin dynamics, and lessening depression, anxiety, and stress (6). Direct correlations with regular exercise and a lower risk of CHD have encouraged many Americans to begin an exercise regimen (7,8,9). However, after a period of time, many people quit exercising for a variety of reasons. This reduction in exercise following a period of regular exercise is known as detraining. Little is known about the effects of detraining on serum lipid levels and lipid storage. Therefore, the objective of this study was to evaluate the effects of exercise detraining in rats by measuring the following factors: body weights, serum TC, HDL-C, TG levels, and storage of lipids.

METHODS

Subjects

Male Fischer 344 rats, 5-6 week-old (86-115 gram), were obtained from Harlan Sprague-Dawley, Inc. (Indianapolis, IN) and all procedures were approved by the institutional animal care review board. Diagnostic kits were obtained from Sigma Chemical Company (St, Louis, MO) for the spectrophotometric determination of serum TC (#352), HDL-C (#352-3), and TG (#336). The TG procedure was also used for the determination of triglyceride extracted from skin flaps. All water used for spectrophotometric assays was de-ionized and then filtered through a Millipore water system.

All animals were housed, in pairs, at the animal care facility located in the Department of Biological Sciences, Illinois State University, Normal, IL. The room temperature was kept at a constant 23°C with a 12 hour light/dark cycle beginning at 700h. All the animals were fed a standard rat chow diet obtained from Harlan Teklad (Madison, WI) containing 4% fat, and water ad libitum.

Exercise Protocol

Rats were randomly assigned to one of three groups (eight rats/group of exercised rats and seven rats in control group). Swimming was the method of physical training utilized in this study. Rats swam as a group in 30-35 gallon waste cans filled 3/4 full with 35°C tap water. Water was drained after each swim and the buckets rinsed thoroughly. Animals were exercised beginning between 1030h and 1200h.

The regular exercise (RE) group trained by swimming for 70 minutes four times per week for the entire 21 weeks of the exercise protocol. The detrained group (DE) trained with equal duration of exercise as the regularly exercised group for the first 16 weeks. This group of rats then discontinued swimming (detrained) for the remaining five weeks of the study. The control group (CO) of rats did not swim during the experiment and were not exercised in any manner. The group was cage confined but handled four days per week in order to standardize any handling effect.

All exercising rats were conditioned to the water for four days before training began by increasing the time swimming in the water from 15, 30, 45, to 60 minutes per session. The rats were then swum 70 minutes per day on Mondays, Tuesdays, Thursdays, and

Fridays. At the completion of each swim, rats were towel dried and returned to their cages. Body weights were recorded for all rats at the beginning of each week before swimming. Animals were fasted overnight and sacrificed 24 hours after the final exercise session. Rats were anesthetized by diethyl ether inhalation. Rats were decapitated and a heart puncture was performed using a 5cc syringe and a 18 gauge needle into the beating heart to remove approximately 2 mL blood from each rat. Blood samples were dispersed into two 1.5 mL polypropylene tubes and allowed to clot for 30 minutes at ambient temperature. The clotted blood was then centrifuged, using a Beckman microcentrifuge, at 12,000 xg for five minutes in a 4°C cold room . The serum was removed and stored at -20°C. Serum samples were analyzed for TC, HDL-C, and TG using the Sigma diagnostic kits. Stomachs were removed, opened, washed with saline and visually inspected. No ulcerations were observed in any of the rats. Other organs (liver, kidneys, adrenal glands) were also removed, weighed and inspected. A skin flap (8-10 cm^2) (which contained fur, skin, muscle, and adipose) was taken from the abdominal area of each rat. The hair was removed by shaving with an electric razor and the flap stored at -20°C.

Lipid was extracted from these samples to evaluate the percent lipid. Prior to extraction, the tissue samples were lyophilized for 24 hours to remove water. Preliminary work indicated that removal of water increased the yield of lipid extracted by our procedure. The lipid extractions were performed by soxhlet extraction using a Kimax soxhlet 34/45 with matching condenser, round bottom flask, and petroleum ether (125mL, 60-80^{o} range) as solvent. The lyophilized tissue, cut into small pieces (approximately 0.5 cm^2) was placed into a Whatman cellulose extraction thimble (30mm x 80mm). The tissue was extracted for 24 hours with a recycle time of 15 minutes. The petroleum ether was removed by rotoevaporation, then by nitrogen gas until a constant weight of the lipid extract was obtained. In preliminary work, a second 24 hour soxhlet extraction of the tissue under the same conditions yielded less than 0.5 % additional lipid. Consequently, a single extraction of each tissue was deemed sufficient. Data for the extracted lipid are reported as gram lipid per 100 g dry tissue weight x 100 and is, therefore, referred to as percent.

The lipid extract was evaluated by thin layer chromatography (TLC) which indicated a major portion of the lipid extracted was in the form of triglycerides. Cholesterol and sterol ester were also identified (relative to authentic standards). The TLC plates were Redi-Plate™ Silica-Gel G TLC plates (20 cm^2) (Fisher Scientific Company, Pittsburgh, PA). The solvent system used for TLC was petroleum ether (60-80^{o}):diethyl ether: glacial acetic acid (80:20:1) (*v/v/v*). Lipids were visualized as black spots following use of a 5% sulfuric acid in methanol spray and gentle heating of the TLC plate.

Statistical Analysis

Variance of weekly body weights, final body weights, and percent lipid extracted from lyophilized skin flaps were compared across groups using analysis of variance (ANOVA) and Fisher's Least Significant Difference (LSD) post test. Differences were considered significant at $p < 0.05$. Means, standard deviations (SD) or standard errors of the mean (SEM) are reported.

RESULTS

Body weights for each group at week 1, 16, and 21 of the experiment were determined. Statistically all three groups of rats had the same body weight at the beginning of the experiment with the RE, DE, and CO groups averaging weights of 152 g ± 11, 146 g ± 9, and 154 g ± 12, respectively. After 16 weeks of training, before the detraining had begun, the mean body weight gain per group was 174 ± 13, 174 ± 18, and 204 ± 17 grams for the RE, DE, and CO respectively. The control group was statistically heavier than the RE and DE groups (Table 1). The percent weight gain per week was about 15 percent higher for the CO group relative to the other rats. Following a five week period of detraining the body weight gains for the groups (relative to week one) were determined to be 197 ± 13, 210 ± 22, and 236 ± 17 grams for the RE, DE, and CO groups, respectively. The CO group was significantly heavier (by about 17%) than the other two groups which did not differ significantly. The final body weights for each group were 349 ± 2, 356 ± 3 and 390 ± 3 g for the RE, DE, and CO groups, respectively. There were no significant weight differences between groups in any of the organ weights (data not shown).

Analysis of total serum lipid concentrations showed no significant cholesterol differences between groups with a mean ± S.D. for the RE, DE, and CO of 41 ± 1.3, 41 ± 3.5 and 41 ± 4.0 mg/dL, respectively. In addition, no significant differences were observed in serum levels of high density lipoprotein-cholesterol concentrations with mean ± S.D. for the RE, DE, and CO which were 28 ± 1.9, 26 ± 3.1, and 28 ± 2.7 mg/dL, respectively. Similarly, there were no differences in serum triglyceride concentrations between the three groups with the RE = 49 ± 11, the DE = 46 ± 10, and the CO = 45 ± 7.4 mg/dL (Table 1).

Table 1. Comparisons of Body Weights, Serum Lipids, and Skin Lipids After 21 Weeks

Parameter	Regular Exercise	Detrained	Control
Body Weight (g)	349 ± 2[a]	356 ± 3[a]	390 ± 3[b]
Serum Triglyceride (mg/dL)	49 ± 11	46 ± 10	45 ± 7.4
Serum Cholesterol (mg/dL)	41 ± 1.3	41 ± 1.3	41 ± 1.3
Percent Skin Triglyceride	4.9 ± 1.6[c]	6.4 ± 2.4[c]	10.2 ± 2.8[d]
Percent extracted Skin Lipid	18.1 ± 0.6[e]	23.9 ± 1.1[e]	29.2 ± 1.0[f]

Values with the same letters are not significantly different at $p < 0.5$

Levels of extracted lipid per gram of dry skin tissue (mean ± S.E.M.) showed the RE group had 18.1 ± 0.6, the DE group 23.9 ± 1.1 and the CO group 29.2 ± 1.0 percent. The CO group is statistically higher (about 30%) than both the RE and DE group which were not statistically different. Examination of the extracted lipid by TLC identified the major component as triglyceride (data not shown). The percent triglyceride extracted per dry skin flap for the RE was 4.9 ± 1.6, the DE was 6.4 ± 2.4, and the CO was 10.2 ± 2.8 which is almost doubled the values of the other two groups. Analysis yielded significant differences between the CO group and the DE or RE groups with no significant difference observed between the RE and DE groups. The percentage of water per skin weight was the same for all three groups (data not shown).

DISCUSSION

A significant training effect was observed on body weight as predicted and our results are similar to those of other studies (1,12). The exercised rats gained 15 % less weight than their sedentary controls on an ad libitum diet of water and standard rat chow. The only difference between the two groups of rats was in levels of physical activity. This significant effect indicates that the training regimen is sufficiently intense to lead to physiological effects although it is much less intense that other reports in the literature (15). The weight gain of 390 grams by the control group of rats at 196 days is equivalent to that shown by Yu, et al., (11) for rats under conditions of no physical exercise.

A detraining effect was observed on body weight. Before the detraining began, the exercised and detrained rat groups had gained weight equally on a week by week basis. The detrained rats gained, on average, 50 % more weight per week than the exercised rats during the first three weeks of detraining. The detrained rats gained weight at a rate which was approximately 20 % faster than the control rats during the first three weeks of detraining. This was unexpected. A possible explanation for this is that the detrained rats were consuming a high number of calories per day while exercising. When these rats were not forced to swim, they continued to consume a large caloric intake, but did not utilize the large number of calories. Consequently, the rats stored the excess calories as tissue fat (triglycerides and cholesterol esters). This suggests that quitting exercise leads to loss of the positive effects on weight control of exercise. This also suggests that the physiological mechanisms controlling weight, hunger and energy metabolism are processes that are slow to adjust.

These results are in agreement with those published by Arnold and Richard (12) which showed approximately a 50% increase in weight in detrained rats as compared to exercised rats after 27 days of inactivity. We suggest that the majority of increased weight gain in the detrained group is attributable to an increase of stored triglycerides in the adipose tissue. As expected, soxhlet extraction of the skin flaps showed that the control rats were storing more lipid (both triglyceride as well as total lipid) per gram of dry tissue weight than the detrained rats and exercised rats. We interpret these data as an indication of the difference in relative percent body fat between the three groups of rats. While not significantly different the RE group had less TG than the DE group demonstrating a trend to greater storage upon detraining.

The RE rats did not accumulate much stored fat in the form of triglyceride in the adipose tissue because of the rigorous training protocol. These data strongly suggest that with regular exercise there is less body weight gain as lipid as compared to the controls. Further, upon cessation of exercise an increase of stored body fat is observed. These findings suggest that detraining increases body weight in the form of stored tissue lipids. In the exercised group of rats, a considerable portion of the lipid extract appeared to be in the form of sterol ester (as estimated by the relative spot sizes of various lipids seen by thin layer chromatography, data not shown). A likely explanation for the observed differences in the type of stored fat is that the exercising rats are esterifying the cholesterol to a greater extent and thereby storing it in adipose and perhaps other tissues such as the

liver. Clearly more work on effects of exercise on the LCAT system as well as various esterases would be of interest.

Serum levels of triglyceride or cholesterol were not significantly different between groups. This is in contrast to the work by others. Simonelli and Eaton (16) reported a reduction in triglyceride secretion as a consequence of chronic exercise. Durstine et al. (17) measured serum lipids on the Zucker rats in response to an endurance running program. They reported a significant reduction (in obese but not lean rats) in serum triglycerides after an 18 week exercise protocol. However, they reported that serum cholesterol levels increased significantly ($p < 0.01$) in the trained obese relative to the sedentary obese rats. For their lean rats, the cholesterol levels did not change in the sedentary relative to the trained rats after 18 weeks.

Since body weight clearly increased in the control group relative to the RE group in our study, there appears to be a net flux of lipid from dietary calories to storage depots such as skin adipose. Upon cessation of the training, the body weight increases (DE group) seen are related to increased storage of lipids. As yet, the regulatory mechanisms which leads to this net storage are not well understood but may be related to changes in hormone sensitive lipase activity. Hormone sensitive lipase is important in the mobilization of triglycerides from adipose (13). Exercise may stimulate this activity while sedentary life style may inhibit this activity. In addition, our data demonstrate that the training effects are lost upon detraining and at about the same rate as they were gained during training. We suggest that a longer detraining time would result in more significant differences between the RE and DE groups and little differences between the CO and the DE groups. Others such as Ghaemmaghami et al. (15) reported reduction in LDL cholesterol levels in rats that swam for 2-6 hours per day, 5 days per week, for 5 weeks. It is possible that a more intensive training regimen might have effectively lowered the serum lipid levels. Our data also suggest that the rat is an inappropriate model to study some risk factors for coronary heart disease such as serum triglycerides and cholesterol levels. This is likely related to the observations that rats have higher HDL-cholesterol levels than humans (14).

ACKNOWLEGEMENTS

The authors wish to thank Kathy Wescom and Kelly Weiss for their assistance with swimming of rats and lipid extractions.

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 211-232

received 4/21/99
accepted 6/7/99

Current Distribution and Status of Amphibians and Reptiles in Cook County, Illinois

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ABSTRACT

The current distribution of amphibians and reptiles was studied in 80 preserves owned and managed by the Forest Preserve District of Cook County, Illinois, from 1995-1997. Widespread habitat destruction and the introduction of non-native species have affected the distribution of the herpetofauna. Thirty-three species (13 amphibians, 20 reptiles) are known or presumed to occur. Three species not known historically or not found during the inventory are suspected to occur. Because of restricted distribution, habitat destruction or low observed numbers, twenty species (63%) are considered rare or uncommon. Three species (9%) are widely distributed, easily found in large numbers and are considered common. Nine species (28%) considered locally common have a restricted distribution but are common where found. Eight species (25%) are considered abundant. Exotic or non-native reptiles, mostly turtles, are occasionally encountered in Cook County forest preserves.

INTRODUCTION

Cook County is Illinois' most heavily urbanized county, encompassing the city of Chicago and its suburbs. Of its 612,132 acres, 61.5% is urban, built-up land (Illinois Department of Natural Resources, 1996). Cook County ranks third in Illinois in area of deep water marsh (1,885 acres, 5.4% of the state), fourth in the state in shallow marsh/wet meadow (5,747 acres, 4.1% of the state), and has 4, 618 acres of shallow water wetland (2.6% of the state). Cook County has 83,518 acres of forest/woodland (2.0% of the state), the greatest acreage of open canopy woods (27,185 acres, 6.5% of state), 75,545 acres of urban grassland (12% of the state), and 3.5% of the state's rural grassland (Illinois Department of Natural Resources, 1996).

The Forest Preserve District of Cook County (FPDCC) was established on November 30, 1915. It contains over 67,000 acres of land managed as wildlife refuge and for recreational use. The majority of Cook County's wetland, prairie, and forest habitats have been altered over time through timber cutting, wetland alteration, agricultural, commercial, and residential use. Further human impact on remaining unprotected habitat is assured, and all habitat types in Cook County have been reduced in size, fragmented, and isolated. This

phenomenon is particularly detrimental to relatively immobile and localized amphibian and reptile populations.

Cook County features 11,819 acres of open water, including 8,923 acres of lakes and rivers, and 2,876 stream acres (Illinois Department of Natural Resources, 1996). The major rivers and tributaries are bordered largely by floodplain forest. Woodland habitats include dry upland forest, wet upland forest (flatwoods), wet hardwood forest, wet bottomland hardwood forest, floodplain forest, and savanna.

Few remnants of true prairie occur in Cook County. Most natural open habitat was eliminated by the settlement practices described above. Fire suppression allowed many non-native, mostly European plant species to invade native ecosystems. Consequently, old field and degraded open shrubland habitats now predominate. Pesticide use probably decimated some sensitive amphibian and reptile species, especially insectivores such as smooth green snakes, *Opheodrys vernalis* (Harding, 1997).

Cook County figures prominently in the literature on the distribution of amphibians and reptiles in the Chicago region. Prior to 1960, Kennicott (1855), Schmidt and Necker (1935), Necker (1938, 1939), Pearsall (1940), Pope (1947), Stille and Edgren (1948) and Edgren and Stille (1948) provided species lists and rudimentary distribution data on over thirty species of amphibians and reptiles. Extensive collections of preserved specimens were made as a result, and were deposited in the Field Museum of Natural History, the Chicago Academy of Sciences, the Illinois Natural History Survey, and out-of state institutions such as the Museum of Comparative Zoology (Harvard University), and the U. S. National Museum (Smithsonian Institution).

Since 1970, herpetological inventories were sporadically conducted at various localities throughout the county. Dancik (1974) reported on native and introduced turtles in the Des Plaines River. Pentecost and Vogt (1976) included Cook County records in their summary of the herpetofauna of the Lake Michigan drainage basin. Sliwinski (1992) surveyed herpetofauna at Poplar Creek Forest Preserve. Anton (1992a) reported on amphibians and reptiles from selected sites in two FPDCC divisions (North Branch, Skokie). Alfaro (1995, 1996) reported on declining amphibians at Tinley Woods. Salamander populations were studied at Spears Woods (Palos Division) by Mierzwa (1998).

This paper summarizes previous studies and the results of the 1995-1997 inventory of amphibians and reptiles in the Forest Preserve District of Cook County.

MATERIALS AND METHODS

Amphibians and reptiles were surveyed from 20 August to 30 October, 1995, and from March to October during the 1996-1997 field seasons. Various survey and collection methods were used to inventory all species found within all twelve FPDCC divisions and 80 individual forest preserves. Some off-site areas (non-FPDCC property) also were inventoried, especially those adjacent to FPDCC preserves.

Drift fences were made of 0.3 m aluminum flashing in 8.0 m lengths. Drift fence arrays were placed along habitat borders (e.g., the margins of marshes or ponds) to intercept

animals moving between these habitats. Fences could be combined to create longer (30 m) fences. Funnel traps were 35 x 50 cm aluminum minnow traps placed at the ends of drift fences. The lower half of the traps was recessed in the substrate, and covered with grass or leaf litter to protect collected animals from the elements and conceal the trap.

Turtle trapping was conducted at selected localities. Because of the high degree of human recreational use at most FPDCC properties, priority was given to secluded sites and those not previously inventoried. Traps (0.6 m wide x 1.3 m long; Nichols Net and Twine Co., Pontoon Beach, IL) were baited with fish and checked daily for one week.

Random dip-netting and seining were used to sample amphibian larvae and aquatic turtles. Seines were 6 m long and 3.3 m wide with 5 mm nylon mesh. Other methods included search and seize, cover turning, minnow-traps, day and night road cruising, and spotting scope/photographic surveys. Data collection included sex, total length, weight, and reproductive condition, if discernible. Frog populations were inventoried from March-June following the methods of Ludwig, et al. (1990).

Dead animals found in good condition in or adjacent to survey areas were salvaged and preserved in 10% formalin and stored in 70% ethanol. Specimens were deposited in the collections of the Field Museum of Natural History (FMNH) and the Illinois Natural History Survey (INHS).

Museum specimens and associated data from the following institutions were examined: American Museum of Natural History (AMNH), Academy of Natural Sciences-Philadelphia (ANSP), Auburn University (AU), Chicago Academy of Sciences (CA), California Academy of Sciences (CAS-SU), Carnegie Museum (CM), Field Museum of Natural History (FMNH), Illinois Natural History Survey (INHS), Illinois State Museum (ISM), University of Kansas (KU), Los Angeles County Museum of Natural History (LACM), Louisiana State University Museum of Zoology (LSUMZ), Museum of Comparative Zoology-Harvard (MCZ) University of California-Berkeley, Museum of Vertebrate Zoology (MVZ), Principia College (PC), Southern Illinois University at Carbondale (SIUC), Tulane University (TU), The University of Florida-Florida State Museum (UF), University of Illinois Museum of Natural History (UIMNH), University of Michigan Museum of Zoology (UMMZ), U.S. National Museum-Smithsonian Institution (USNM), and the collection of Harlan Walley (HDW).

Acronyms of the above institutions are used in the text to indicate material examined. Verified indicates the identities of the specimen(s) was verified by the institution's collection staff at the author's request. Examined indicates personal examination of the specimen(s) by the author. All specimens in the CA, FMNH and INHS collections cited in the text were examined. Localities on specimen tags, catalog entries, and database printouts were visited if possible to verify the continued presence of uncommon, rare, and federal or state-listed species, and the continued presence of suitable habitat.

Amphibians and reptiles were photographed on 35 mm color slides and black-and-white prints. They were deposited in the photo collections of the FPDCC, Illinois Natural History Survey (INHS), and Southern Illinois University at Carbondale (SIUC). Documenta-

tion was in number of species within each FPDCC division (Fig.1). Specific preserve names are not mentioned in the text.

During this survey, abundant species were defined as those found in 9-12 FPDCC divisions and more than 20 preserves; common species, those found in 7-8 divisions and 15-20 preserves; uncommon species, those found in 5-6 divisions and 10-14 preserves, and rare species, those found in 4 or less divisions and 9 or less preserves. In addition, a species was considered locally common if it was readily observed in certain localities having suitable habitat.

RESULTS

Species frequency

Thirteen amphibian and nineteen reptile species were found in the twelve FPDCC divisions and eighty preserves surveyed; a revised checklist of amphibian and reptile species in Cook County is shown in Table 1.

Distribution and abundance varied among species. Spring peepers (*Pseudacris crucifer*), Blanding's turtles (*Emydoidea blandingii*), and red-bellied snakes (*Storeria occipitomaculata*) were generally distributed in Cook County but infrequently observed, even in optimal habitats. The northern water snake (*Nerodia sipedon*), and queen snake (*Regina septemvittata*), had restricted or sporadic distributions throughout Cook County, but were common or easily observed at some localities.

SPECIES ACCOUNTS

Species found during this survey

AMPHIBIANS

Blue-spotted salamander, *Ambystoma laterale*. Although this species is found in only six counties in northern Illinois, it was locally common, being found in 8 FPDCC divisions and 22 preserves.

Spotted salamander, *Ambystoma maculatum*. This ecologically sensitive hardwood forest species is sporadically distributed in large FPDCC holdings. Alfaro (1995) reported declines in this species at 4 sites in Tinley Creek Division from 1973 to 1995. It was found in 3 FPDCC divisions and 7 preserves.

Tiger salamander, *Ambystoma tigrinum*. This is the largest, most widespread salamander species in Cook County, utilizing both open and forested habitats. It was found in 10 FPDCC divisions and 18 preserves.

Eastern newt, *Notophthalmus viridescens*. This rare, sensitive species is restricted to forested habitats. They were found in 3 FPDCC divisions and 6 preserves.

Red-backed salamander, *Plethodon cinereus*. This rare woodland salamander was found in 1 FPDCC division and 1 preserve. Two adults (1 in 1995, 1 in 1996) were found in hardwood forest under rotting logs near a pond containing *Sphagnum* moss hummocs. The preserve in which they were found is the oldest in the FPDCC. Smith (1961:54)

reported the distribution of this species from the extreme eastern edge of Illinois, and considered it "inexplicably rare or perhaps extinct in northeastern Illinois". Smith (1961:54) cited only one old (1933) specimen (FMNH 19256-examined) and a published record from Cook County.

American toad, *Bufo americanus*. This is one of the most widely distributed and abundant amphibians in Cook County. It was found in all 12 FPDCC divisions and 28 preserves.

Gray tree frog, *Hyla chrysoscelis/H. versicolor* complex. This complex consists of two morphologically similar species, the eastern gray tree frog (*H. versicolor*- tetraploid) and Cope's gray tree frog (*H. chrysoscelis* - diploid). Populations at one Northwest Division preserve are referable to the latter, while a population at a second Northwest Division preserve was not identified. *Hyla versicolor* is more widely distributed in the southern portion of the county. Both species are locally common, being found in 5 FPDCC divisions and 10 preserves.

Spring peeper, *Pseudacris crucifer*. This frog was found in 5 FPDCC divisions and 10 preserves. They were heard calling at a preserve in Tinley Creek Division in 1996, but Alfaro (1996) did not find this species at study areas in 4 adjacent Tinley Creek preserves. Their numbers appear to vary widely at each locality during the breeding season, and estimating their abundance is difficult. In 1996 a small chorus was heard and a specimen collected at a Skokie Division preserve, which is the northeasternmost population of the species in Cook County.

Western chorus frog, *Pseudacris triseriata*. This is an abundant and widespread species in Cook County. It was found in a variety of aquatic habitats on and off FPDCC property. It was documented from 11 FPDCC divisions and 22 preserves.

Bullfrog, *Rana catesbeiana*. This is Cook County's largest and most abundant frog. They were observed or heard calling from marshes, lakes, large ponds and the Des Plaines River in all 12 FPDCC divisions and 32 preserves. They have been widely introduced and can be found in all fishing lakes in Cook County.

Green frog, *Rana clamitans*. This locally common frog was found in 8 FPDCC divisions and 11 preserves. It reaches its greatest abundance in rocky streams and ponds with abundant emergent aquatic vegetation. Green frogs may have been displaced or possibly extirpated by bullfrogs at some FPDCC preserves, but data attributing declines in *R. clamitans* to bullfrogs is anecdotal or lacking.

Northern leopard frog, *Rana pipiens*. This species was found in marshes, wet meadows and fields adjacent to permanent or semi-permanent water. Populations are often localized and may undergo cyclical flutuations. From 1979 to 1982, they were seldom observed at preserves in 3 FPDCC divisions where they were once common (Anton 1992a). Declines have been reported (Ludwig, et al. 1990; Pentecost and Vogt, 1976), however, during this survey, they were encountered at localities where they were previously unreported or thought to have declined. They were found in 9 FPDCC divisions and 27 preserves.

Wood frog, *Rana sylvatica*. This rare, highly secretive woodland frog was found in 3 preserves in 3 FPDCC divisions. Smith (1961) stated that *R. sylvatica* was not abundant even in optimal habitat. Pentecost and Vogt (1976) considered it an ecologically sensitive species. Wood frogs were known from specimens (CA 19446-7; FMNH 162068-69, 162169) collected between 1946 and 1948 from 2 preserves in Des Plaines Division. In 1996, two newly metamorphosed individuals were found at one Des Plaines Division preserve fifty years after they were last collected there. Alfaro (1995, 1996) did not find the species at four study areas in Tinley Creek Division.

REPTILES

Eastern spiny softshell turtle, *Apalone spinifera*. This large aquatic species was found in the Des Plaines River and other large bodies of water on and off FPDCC property in 6 FPDCC divisions and 5 preserves.

Common snapping turtle, *Chelydra serpentina*. This is the largest and one of the two most abundant turtle species in Cook County. They were found in all aquatic habitats, including quarries, marshes, ponds, fishing lakes, ditches, rivers, and streams. They were particularly abundant in the Des Plaines River and were found in 9 FPDCC divisions and 29 preserves.

Painted turtle, *Chrysemys picta*. This common and highly visible turtle was county-wide in distribution, occurring in 8 divisions and 20 preserves. Habitats in Cook County included marshes of all sizes, man-made lakes, ponds, quarries, and in oxbows and slow backwater sections of the Des Plaines River.

Common map turtle, *Graptemys geographica*. This turtle is known in Cook County from 1 specimen (FMNH 2925) collected in Jackson Park Lagoon in 1919. During the study, it was found only in the lower Des Plaines River near the Calumet-Sag channel, and in a preserve in Sag Valley Division. It is found in the Des Plaines River in adjacent Du Page (Ludwig, et al, 1992) and Will Counties (Redmer and Anton, 1993; Redmer, 1994).

Blanding's turtle, *Emydoidea blandingii*. This turtle was found in 5 FPDCC divisions and 5 preserves. It was most often observed in large marshes and quarries with abundant aquatic vegetation, and in isolated floodplain ponds of the Des Plaines River. Only large adults of this long-lived, low-fecundity species (Congdon, 1993) were encountered during the study. On 1 January 1999 it was listed as threatened in Illinois (Redmer and Kruse, 1998).

Common musk turtle, *Sternotherus odoratus*. This small, secretive turtle was found in 4 FPDCC divisions and 6 preserves and occurs in the large quarry complexes in the Lemont area (Sag Valley Division). One (INHS 12687) was killed by fishermen at a lake in Thorn Creek Division in 1996. The species persists at a locality in a heavily industrialized area in Calumet Division.

Eastern box turtle, *Terrepene carolina*. This is presumed to be the only native species of box turtle in Cook County. Four individuals, including a gravid female (FMNH 252410) were found DOR on the Calumet Expressway (I-394) near Goodenow, Will County, ca. 4 km. south of the county line (Anton and Redmer, 1996). In 1996, an adult female (INHS

13074) was found DOR on the east shoulder of the Calumet expressway (I-394) at the I-80/294 interchange. Populations of this turtle occur in Lake County, Indiana just over the state line. Pearsall (1940) included this species on his list of Forest Preserve District fauna.

Red-eared slider, *Trachemys scripta.* This species was found in 7 divisions and 7 preserves. Populations in Cook County are believed to be introduced, though the natural range of the species approaches the Chicago region (Pope, 1947). Therefore, the delineation of its range in northern Illinois is problematic. Concerns over *Salmonella* infection halted the sale of pet shop hatchlings in the late 1970s. It is most common in large, man-made lakes and backwaters of the Des Plaines River.

Fox snake, *Elaphe vulpina.* This large, locally common snake inhabits old fields, prairies, marsh margins, and open woodland in the northwestern and southern portions of the county. Quarries, abandoned buildings, and foundations were frequented. They were found in 4 FPDCC divisions and 7 preserves.

Milk snake, *Lampropeltis triangulum.* This fossorial constrictor is secretive and seldom seen in Cook County. Abandoned buildings, old foundations, dilapidated stone walls, and quarries in open woodland or prairie margins were preferred habitats. They were found in 4 FPDCC divisions and 5 preserves.

Northern water snake, *Nerodia sipedon.* This locally common snake was found in rocky creeks and streams and on lake, marsh, and pond margins with ample cover, usually rocks. Quarries and dolomite piles near bridges and fishing lakes often support large populations. It was found in 2 FPDCC divisions and 4 preserves.

Smooth green snake, *Opheodrys vernalis.* Widespread pesticide use and destruction of prairie habitat have resulted in populations of this small insectivore being reduced to widely scattered colonies (Smith, 1961). Original habitats in Cook County included sedge meadows, mesic prairie, old fields, and vacant lots. They were found in 6 FPDCC divisions and 5 preserves.

Graham's crayfish snake, *Regina grahamii.* This rare semi-aquatic inhabitant of prairie ponds and marshes was found in only 1 preserve. The distribution of the species in the Chicago region is poorly known. Habitats in Cook County included a group of small (2-3 ha.) heavily vegetated ponds in Sag Valley Division. Individuals were observed in 1991and 1995 at these ponds. The observations in 1991 were documented with 2 specimens (FMNH 245712, 247523).

Queen snake, *Regina septemvittata.* This locally common semi-aquatic snake was found in only 1 FPDCC division and 2 preserves in southern Cook County during the survey. Habitats included rocky sections of creeks in semi-open woodland and a large, FPDCC-owned quarry complex near Lemont, which featured ample dolomite slab and vegetation cover. This snake and *Regina grahamii* are dietary specialists, feeding almost exclusively on newly molted crayfish.

Brown snake, *Storeria dekayi*. This species was found in all 12 FPDCC divisions and 23 preserves. It was considered abundant by Smith (1961). Habitats in Cook County were forest edge, open floodplain woodland, and old fields. They also were found in disturbed habitats both off district and on FPDCC property, even in urbanized areas.

Red-bellied snake, *Storeria occipitomaculata*. This small, secretive snake was found in 3 FPDCC divisions and 5 preserves. Though considered uncommon except in the morainal regions of Cook and Lake counties (Smith, 1961), it was considered common throughout the broadly-defined Lake Michigan drainage basin (Pentecost and Vogt, 1976).

Plains garter snake, *Thamnophis radix*. This snake was found in all 12 FPDCC divisions and 20 preserves during the survey. It occurs county-wide, even in areas of high urbanization and disturbance. Habitats in Cook County included old fields, abandoned farmland, and marsh environs. This characteristic prairie species was considered common to abundant in the Chicago region (Pentecost and Vogt, 1976; Pope, 1947; Smith, 1961).

Common garter snake, *Thamnophis sirtalis*. This widespread species is probably the most common snake in the Chicago region. A current summary of research on this ubiquitous species is provided by Rossman, et al. (1996). *Thamnophis sirtalis* was found in 11 FPDCC divisions and 21 preserves.

Massasauga rattlesnake, *Sistrurus catenatus*. This rare, secretive pit viper was found in only 1 FPDCC division and 2 preserves. Reports of its presence in southeastern Cook County on FPDCC property need verification. This snake is known from only 3 northeastern Illinois counties (Cook, Lake, Will). It was presumed extirpated in adjacent Du Page County (Ludwig, et al. 1992). In 1994, this snake was placed on the Illinois list of endangered species. Massasaugas are essentially prairie species, but also occupy forest edge and old field habitats, and may persist in disturbed areas where habitat is protected (Anton, 1992b). It apparently breeds every 2-3 years across most of its U.S. range (Anton, 1992b). This factor, plus small litter size, continued habitat destruction, fragmentation and genetically isolated populations, make this long-lived, r-selected species vulnerable to extirpation. Anton (1992b) and Wright (1941) summarized the natural history of this unique snake in northeastern Illinois.

Amphibians and reptiles not found during this survey but considered part of the historical fauna of Cook county

Cricket frog, *Acris crepitans*. Smith (1961) called this small frog the most common amphibian in Illinois. It underwent unexplained declines in the 1970s (Vogt, 1981), and was placed on the endangered species list in Wisconsin. Declines in Illinois were summarized by Mierzwa (1989). *Acris crepitans* can adapt to disturbed habitats, such as quarries. Natural habitats include pond, lake and stream margins. They are found in shallow water with abundant emergent vegetation and a mud, silt, clay or gravel substrate. A population near Joliet is the only one known in the Chicago region (Redmer and Anton, 1993). Examination of specimens collected from 1927 to 1970 showed this frog was once widespread in Cook County, being found in areas within 8 FPDCC divisions. Large numbers were collected in Palos Division in the mid-1940s. An FPDCC-owned quarry complex near Lemont appeared to contain suitable habitat for *A. crepitans*, but none were

heard or collected in three years of survey work. The cricket frog is presumed extinct in Cook County.

Fowler's toad, *Bufo fowleri*. This toad is usually found in sandy areas, such as oak savannas, sand dunes, xeric prairies near Lake Michigan and sandy-soil areas in open woodland (Pentecost and Vogt, 1976). Despite Pearsall's (1940) inclusion of this toad on his FPDCC faunal list, efforts by herpetologists and FPDCC staff to find them in or adjacent to the Chicago Lake Plain in Calumet and Thorn Creek divisions were unsuccessful. Specimens from the Chicago region are few, suggesting that populations in northeastern Illinois were relicts. A specimen (CA 18417) collected at Bullfrog Lake (Palos Division) in 1966 was identified as an American toad, *B. americanus*. Three specimens (CA 127) from Lake County, Indiana were mistakenly labeled "Cook County". A single locality in northeastern Cook County plotted as a solid circle on Smith's (1961:77) map refers to a specimen (MCZ 500-verified), collected in Evanston in 1886. If this record is valid, *Bufo fowleri* is most likely extinct in Cook County.

Four-toed salamander, *Hemidactylium scutatum*. This plethodontid salamander is listed as threatened in Illinois (Illinois Endangered Species Protection Board, 1994). This glacial relict is currently known from 10 Illinois counties (Anton, et al., 1998; Brandon and Ballard, 1991). Smith (1961:52) considered this salamander extremely rare in Illinois. Often considered a bog species, *H. scutatum* has been found in a variety of habitats, including deciduous and coniferous forests, *Sphagnum* bogs, and seepage areas in oak, hickory, and maple-dominated woodland. A consistent feature of the habitat is undisturbed mature forest near water in the form of fishless woodland pools and seeps, and ample damp cover, such as mosses and leaves (Anton, et al., 1998). All specimens from Cook County (CA, FMNH, USNM) were collected before 1925. Pearsall (1940) listed *H. scutatum* as a component of the FPDCC herpetofauna. In 1995, a population was discovered in Will County, and is the first record in the Chicago region in over 65 years. A preserve in Northwest Division appears to contain suitable habitat, but a reported sighting in 1978 could not be verified. This preserve also is the oldest FPDCC property. Although these factors suggest that four-toed salamanders may be found at this locality in the future, the four-toed salamander is likely extirpated in Cook County.

Mudpuppy, *Necturus maculosus*. This aquatic species is the largest salamander in the Chicago region. Habitat includes lakes, lagoons, rivers and large creeks. Mudpuppies are difficult to collect except with electrofishing equipment (Smith, 1961). They are considered rare in adjacent Du Page County (Ludwig, et al. 1992), and its status in surrounding Lake and Will counties remains unknown. Most specimens collected between 1880-1980 came from Lake Michigan, and they still occur at some localities along the Lake Michigan shoreline. Specimens (FMNH 142237, 245677-79, 245692-93) were collected between 1964 and 1979 at Wolf Lake (off-site, Calumet Division), and the presence of a reproducing population there was reconfirmed in 1997. Two juveniles and 1 subadult were found by the author at this site on 11 July 1997; a juvenile specimen (INHS 13170) was collected. Pearsall (1940) included mudpuppies on his FPDCC faunal list. Pope (1947) suggested that mudpuppies may occur in the Des Plaines River, but cited no specimens. Although county-wide electrofishing censuses conducted over a 10-year period by FPDCC fisheries biologists failed to collect any specimens on FPDCC property, the species still occurs in Cook County.

Plains leopard frog, *Rana blairi.* This recently described prairie species (Mecham, et al., 1973) is similar to the northern leopard frog, but was recognized as a distinct species based on morphological traits and differences in breeding call. It has a poorly defined range in the midwestern U.S., being restricted to the prairie peninsula in the eastern portion of its range (Conant and Collins, 1991). Brown and Morris (1990) did not find *R. blairi* to be abundant at any locality in Illinois. This frog occupies a variety of habitats, including disturbed areas adjacent to agricultural land. This distribution may be the result of the destruction of most Illinois prairie habitat by agricultural practices (Brown and Morris, 1990). The closest known localities for this species are in Crete, Monee and Wilmington Townships, Will County (Mierzwa, 1988; Brown and Morris, 1990). Searches of habitat in southern Cook County considered suitable for the species were unsuccessful, and *R. blairi* remains undocumented. Its status is uncertain in Cook County.

Spotted turtle, *Clemmys guttata.* This Illinois State Endangered Species has not been found in Cook County since 1950. A specimen examined (INHS 6013) was collected in 1950 "near Illinois-Indiana line". A specimen (UIMNH 2284-examined) collected in 1927 from "a small pond just beyond the Illinois end of Wolf Lake, Cook County" (Cahn, 1937), was cited by Smith (1961), who considered the record dubious. Pearsall (1940) did not include *C. guttata* in his FPDCC faunal list. Another specimen (CA 18549) gives only "Palos Hills" as locality data, and was collected in 1942. To date, the only viable *Clemmys guttata* populations in Illinois are in Will County, where an intensive life-history study and monitoring regimen is being undertaken by Will County Forest Preserve District wildlife biologists. Destruction of wetland habitat and illegal collecting for the pet trade are the greatest threats to this long-lived, low-fecundity species throughout its range. *Clemmys guttata* is most likely extinct in Cook County.

Kirtland's snake, *Clonophis kirtlandii.* This small, rare fossorial snake is listed as threatened in Illinois (Illinois Endangered Species Protection Board, 1994), and was proposed for federal listing as a Category 2 species (Dodd, et al., 1985). A current summary of the distribution and status of this species was provided by Bavetz (1993). *Clonophis kirtlandii* is a glacial relict (Smith, 1961), and was considered rare in the Chicago area (Pope, 1947; Pentecost and Vogt, 1976). Pearsall (1940) included *C. kirtlandii* on his FPDCC faunal list. The majority of specimens and published records from the Chicago region are from Cook County, and represent areas in 5 FPDCC divisions. The type specimen (USNM 1514) was collected by Robert Kennicott in 1856. A 1993 photograph and specimen (SIUC R-2461) of an individual from Tinley Creek Division is the only current documentation of this species from Cook County. In 1998, one was found in a small prairie remnant (off-site) in Palos Division. A population of these snakes persists in Will County (Anton and Redmer, 1996). Some habitat remains in Des Plaines Division, but the most recent observations there date to 1986. Disturbed or urban habitats near wetlands that may still harbor these snakes are vulnerable to continued habitat destruction. Direct threats include burns (controlled and illegal), vehicular traffic, and mowing operations (Bavetz, 1993). Threats to this species from agricultural practices were reported as early as the 1890s (Garman, 1892). Protection of habitat for burrowing crayfish was suggested (Tucker, 1994), as *C. kirtlandii* appears to depend on crayfish burrows for shelter and hibernacula. *Clonophis kirtlandii* still occurs in Cook County, although none were found on FPDCC property during this survey.

Six-lined racerunner, *Cnemidophorus sexlineatus*. Only a published record of this fast, diurnal lizard exists for Cook County. Smith (1961) cited "forest preserves", based on Pearsall (1940), but did not specify which FPDCC property. Smith (1961: 166) plotted this record on his map for the species in what is Calumet Division. Two preserves in this division contain sand areas, but pitfall traps failed to collect any specimens. These preserves are now heavily overgrown with non-native vegetation which has shaded out what were once open sand prairie remnants. Racerunners are common at Indiana Dunes National Lakeshore and other localities in adjacent Lake and Porter counties, Indiana. In the Chicago area, racerunners are known from large sand areas in Grundy, Kankakee, and Will counties. Despite reported sightings of this active, diurnal animal, none were collected during this survey, and it remains undocumented by specimens. Its status in Cook County is uncertain, and it may now be extirpated.

Racer, *Coluber constrictor.* This large, active, diurnal snake inhabits forest edge, old fields, and open woods throughout the Lake Michigan drainage basin (Pentecost and Vogt, 1976). It prefers sand areas (sand prairies, open sand woodland). The closest known localities are both in Will County. Pearsall (1940) included it on his list of FPDCC herpetofauna. Three specimens are extant; Pope (1947) mentions a specimen (CA 58, collected pre-1930) from an unspecified locality in Cook County. A juvenile (USNM 6389-verified) was collected before 1864 and has only "Cook County, Chicago" for locality data. A Du Page County specimen (FMNH 41221, juvenile) was collected in 1940 at 31st St. and York Road, near Fullersburg Woods at the Cook County line; it was found in the basement of a home and may have been transported from another locality. No other specimens are known from Cook County. This snake requires large (>1500 ha.) tracts of relatively undisturbed, semi-open habitat, preferably in sandy areas. Few such areas remain in Cook County. The status of *C. constrictor* in Cook County is unknown and it may now be extirpated in Cook County.

Rat snake, *Elaphe obsoleta.* This large (>100 cm) snake is known from only two specimens (CA 290, FMNH 19491), both collected before 1935 from near railroad areas in Thorn Creek Division. These specimens form the basis for its inclusion in Pearsall's (1940) FPDCC fauna list. Both specimens were examined and are referable to the *E. o. spiloides* (gray rat snake) or *E. o. lindheimeri* (Texas rat snake) phenotypes. This, plus the strong possibility of their arrival as stowaways on rail traffic, make their locality data suspect. No suitable habitat exists in Cook County and no specimens have been found since 1935. In Will County, a single DOR specimen (INHS 11186) was found in Monee Township in 1993 (D. Mauger, pers. comm). Heavily wooded riparian areas, featuring dolomite bluffs surrounded by open woodland, are preferred habitat in central, northwestern, and southern Illinois. Large, undisturbed tracts of land are required for viable populations to exist. It is presumed that individuals encountered in the immediate Chicagoland area are escaped pets. Like the racer (*Coluber constrictor*), individuals of this species would be found DOR where a reproducing population existed, and sightings would be more frequently reported. The status of the rat snake in Cook County is unknown.

Five-lined skink, *Eumeces fasciatus*. This lizard inhabits forest edge, pine barrens, oak forest, and northern mesic (xeric hardwood) forest, where it frequents logs, dead trees,

and abandoned buildings (Pentecost and Vogt, 1976). Rocky areas also are used (Smith, 1961). They are wary, fast and extremely hard to capture, making documentation difficult. *Eumeces fasciatus* is very rare north of the Shelbyville Moraine (Smith, 1961), and in the Chicago area (Pope, 1947). Any remaining northeastern Illinois populations are presumably glacial relicts. Pearsall (1940) did not include *E. fasciatus* on his list of FPDCC fauna. All specimens from Cook County were collected in the late 1800s (CA 24;USNM 4995-verified), and between 1912 and 1925 (FMNH 2849-50). Locality data for these specimens is not specific, and the localities have been developed since the 1930s. In 1991, a juvenile from a preserve in Sag Valley Division was photographed. The two poor-quality color slides (SIU-Carbondale and FPDCC photo collection) are the only documentation of this species in Cook County and the entire Chicago region since the 1920s. The status of the five-lined skink in Cook County remains unknown.

Eastern hognose snake, *Heterodon platyrhinos*. Unsubstantiated reports of this distinctive snake existed between 1986-1991 from Thorn Creek Division, where they may have been introduced. Despite intensive searches in this area, no specimens were found during the survey. Specimens of *H. platyrhinos* presumably were the basis for which Pearsall (1940) included it in his faunal list. The specimens are old and came from sites not owned by the FPDCC (CA 33, collected 1889; FMNH 3001, collected 1880; CA 13796, collected 1946). The status of the hognose snake in Cook County is unknown.

Slender glass lizard, *Ophisaurus attenuatus*. Little is known about the ecology or habits of this legless lizard in Illinois (Smith, 1961). Smith (1961:164) considered this species "inexplicably rare", though state-wide in occurrence. A specimen (CA 19, collected 1857) had only "Cook County" for locality data. Another specimen (FMNH 2971, collected pre-1860) is from "Palos Park". Smith (1961) overlooked the specimens or may not have considered the locality data valid; he plots no solid circle on his distribution map for the species. Pope (1947) considered *Ophisaurus attenuatus* rare in the Chicago area. He reports a pre-1860 specimen (CA 18) taken at Evanston. Pearsall (1940) did not include this lizard on his FPDCC fauna list. Glass lizards inhabit sand areas, but are found in other open habitats (Pope, 1947; Smith, 1961). Pentecost and Vogt (1976) reported *O. attenuatus* from sand or muck prairie, oak savanna and pine barrens, but described it as rare in the Lake Michigan drainage basin. During the survey, searches for this lizard were conducted in sandy areas in Calumet and Thorn Creek divisions on or adjacent to the Chicago lake plain. Glass lizards were reported from a preserve in Calumet Division as recently as the late 1980s. Four were taken in pitfall traps during small mammal surveys in 1986 (C. Anchor, pers. comm),but none were collected or photographed, and they have not been found at this locality since. The status of Glass lizards both on and off FPDCC property in Cook County is unknown.

Western ribbon snake, *Thamnophis proximus*. This snake is usually found near water in high-quality habitats. They inhabit swamps, marsh edges, sandy areas of southern lowland forest, and occasionally upland woods (Pentecost and Vogt, 1976; Smith, 1961). Although Kennicott (1855) considered them "common" in Cook County, *T. proximus* is considered rare over much of its range and in the Chicago area (Pentecost and Vogt, 1976; Pope, 1947). Smith (1961:226) called the range of *T. proximus* problematical; he described it as common in the Mississippi River bluffs and in southwestern Illinois, but extremely rare elsewhere in the state. Ribbon snakes are reported to be more sensitive to

habitat modification than other members of the genus (Pentecost and Vogt, 1976). Three specimens from Cook County are listed in collections. USNM 8062 was verified as *T. proximus,* its locality data showing only "Cook County, Chicago". MCZ 23, cataloged as *T. proximus*, was collected by Kennicott in the same period, but was missing from the MCZ collection and its identity could not be verified. Because of the likelihood of misidentification, ribbon snakes must be collected for positive identification. They were not included in the list of FPDCC fauna by Pearsall (1940). The only recent records of *T. proximus* in the Chicago region are observations in Lake County in the early 1980s (undocumented by specimens), and one specimen (INHS 12096) from Will County. *Thamnophis proximus* has not been found in Cook County since the turn of the century and it may now be extirpated.

Amphibians and reptiles erroneously reported from Cook county

The following species have been recorded from Cook County and are documented by specimens except where noted. The records are believed to be erroneous due to cataloguing errors, misidentification, or mislabeling. In some cases, specimens may have originated in southern Illinois, particularly those collected by Robert Kennicott, who collected extensively in that region. Others represent introductions of non-endemic species. All specimens are old (1850-1930s), and none have been found in the county since.

Desmognathus quadramaculatus (black-bellied salamander). Data for the single specimen (USNM 3823-verified) of this southeastern U.S. and Appalachian species shows "Cook County" and the collector, Kennicott. Smith (1961) pointed out that the locality data for this specimen has to be incorrect.

Plethodon glutinosus (slimy salamander). Four specimens (UMMZ 77009-verified) exist. No dates of collection are given, only "Chicago". Two other specimens (USNM 3775, 9481-verified) list localities "Cook County, Aux Plaines River, West Northfield" and "West Northfield" respectively. Both were reportedly collected by Robert Kennicott. A lack of additional specimens and the isolation of Kennicott's material from the largely southern and eastern range of the species in Illinois prompted Schmidt and Necker (1935, in Smith, 1961) to eliminate *P. glutinosus* from Cook County's fauna.

Pseudotriton ruber (red salamander). This eastern species was supposedly represented by a pre-1890 specimen from "Aux Plaines", but no specimen was found in any of the museum collections surveyed. Schmidt and Necker (1935) questioned the record and deleted *P. ruber* from their list of Chicago region amphibians and reptiles. This species has not been found in Illinois, and Smith (1961) eliminated it from the state's herpetofauna.

Rana palustris (pickerel frog). No specimens of this frog are known from Cook County. Specimens from Kane and McHenry counties collected before 1950 were the basis for its presumed occurrence in northwestern Cook County (Smith, 1961:102). Pearsall (1940) did not include this species on his list of FPDCC fauna. It was included on subsequent faunal lists, but the basis for this is unknown. Pickerel frogs can be mistaken for aberrantly patterned leopard frogs (*R. pipiens*). A newly-metamorphosed specimen believed to be this species was collected in Spring Creek (Poplar Creek Division) in 1991, but was later identified as *R. pipiens*. Some marginal habitat exists at this locality, which features

a cold, spring-fed, well-vegetated stream. Limited canopy cover at this locality precluded its being condsidered optimal habitat. A 1973 report from Tinley Creek Division cited by Alfaro (1995) is suspect; no suitable habitat exists at this locality, and no specimens have been collected there since. Pickerel frogs were not found during searches of seepage areas on the Cook-Will county line (Mierzwa, 1988). Widespread destruction of spring-fed watersheds in the Chicago region may have eliminated any suitable habitat for *Rana plaustris*.

Graptemys pseudogeographica complex (false map turtles). Dancik (1974) reported the capture of a single *G. kohni* (Mississippi map turtle) from the Des Plaines River in Salt Creek Division. They also are known from two specimens (FMNH 5573, 5615), purchased from a Chicago market in 1923. These were examined and are referable to the false map turtle (*G. pseudogeographica*) complex. The species was reported from northern Illinois by Cahn (1937), and postulated to occur statewide (Smith,1961). They were reported from adjacent Du Page County by Ludwig, et al. (1992), where individuals from two localities were considered introductions. False map turtles were not observed at any locality during the inventory, and Cook County populations are presumed to be introduced.

Sceloporus undulatus (eastern fence lizard). This is a common species of heavily timbered regions of southern Illinois and the southern midwest. One specimen (USNM 9082-verified) bears the locality data "Cook County, Northfield". Another (FMNH 11270) was collected in1930. Its locality data reads "Chicago, Illinois, in vegetable shipment". This species has not been found north of Shelby County (Smith, 1961), and it is presumed that the USNM specimen bears erroneous data.

Scincella lateralis (ground skink). This small, secretive southern species is not found north of Mason County in central Illinois. A single specimen (USNM 9302-verified) was reportedly collected from "West Northfield", and is presumably a Kennicott specimen. The locality data for this specimen is presumed erroneous. No recent specimens or published reports of this species exist from northern Illinois.

Carphophis amoenus (worm snake). What Kennicott (1855) called *Celuta helenae* has never been found in Cook County. His inclusion of this predominately southern species as a component of the Cook County fauna is suspect. A survey of 22 museum collections revealed no specimens of *C. amoenus* from northeastern Illinois.

Diadophis punctatus (ring-necked snake). A single specimen (CA 924, collected 1878) has only "Cook County" for data. Both catalog entry and jar label read "the locality for this specimen is questionable". Schmidt and Necker (1935:61) suggested the "transport of terrarium individuals, and we accordingly omit the species from our list until it can authentically be traced to our area". The specimen may have originated in Kansas (Kennicott, 1859). Garman (1892) considered it uncommon; all localities he cited were from southern Illinois. None have been found in Cook County, and the closest known locality in the Chicago region is the Indiana Dunes National Lakeshore (Porter Co.), where it is represented by a recent (1991) specimen (FMNH 246402).

Lampropeltis calligaster (prairie king snake). One specimen of this large prairie species exists (CA 90). It was collected by Kennicott before 1856. The locality in the ledger was handwritten in ink only as "Ill" with "Cook County" stamped into the locality field at a later date. The specimen was initially identified as *Elaphe vulpina*, and later re-identified as *L. calligaster* by Howard K. Gloyd. Examination of an entry referring to the same specimen in an older ledger showed the locality "N. Illinois" with "Cook County" entered later in the locality field. The data could have been misapplied to a specimen from Kansas (Kennicott, 1859). This specimen was part of the Northwestern University collection obtained by the Chicago Academy of Sciences around 1930. The northernmost localities for this snake are Kankakee, Marshall and Rock Island counties in central and western Illinois. Garman (1892:294) considered it an uncommon inhabitant of prairies throughout the state, and gave no northern Illinois records. Blanchard (1921) makes no mention of this or any other specimen from Illinois north of Pekin (Tazewell County).

Opheodrys aestivus (rough green snake). One specimen (UMMZ 3771-verified) was reportedly collected by Kennicott at "West Northfield" around 1850. This semi-arboreal inhabitant of lowland areas and swamps has not been found north of the Shelbyville Moraine (Smith, 1961).

Pituophis melanoleucus (bullsnake). In 1996 a juvenile was caught in a rodent sticky trap behind a restaurant in Calumet City near the IL-IN state line (P. Strand, pers. comm.). It was presumed to be an escaped pet. Sand prairie remnants along powerline right-of-ways could support small, isolated populations, but it is unlikely that these could survive urbanization over time. No specimens from Cook County exist in museum collections surveyed, and Pearsall (1940) omitted it from the FPDCC fauna. Bullsnakes are often mistaken for the similarly patterned fox snake, *Elaphe vulpina*, and reports of "bullsnakes" received at nature centers in Cook County usually involve fox snakes. The inclusion of bullsnakes on post-Pearsall (1940) FPDCC faunal lists is erroneous. Bullsnake populations in the Chicago area are known only from northwest Indiana and the Kankakee Sand Area Section of Grundy, Kankakee and Will counties. Sightings of living and DOR individuals of such a large (>2m) snake would be reported if reproducing populations existed in Cook County. Similar logic applies to *Coluber constrictor* and *Elaphe obsoleta.*

Thamnophis sauritus (eastern ribbon snake). Three specimens of this snake exist in museum collections. CA 371 was cataloged as a *T. proximus* but was verified by the author as *T. sauritus*. It was collected by Robert Kennicott around 1860 but had no specific locality data, and the record is presumed to be erroneous. MCZ 3268, (misidentified as *T. proximus* and verified as *T. sauritus*), was collected in 1865. UMMZ 4079, verified as *T. sauritus*, was collected by Kennicott at "West Northfield" around 1860. *Thamnophis sauritus* is listed as endangered in Illinois (Illinois Endangered Species Protection Board, 1994). The nearest *T. sauritus* record documented by a specimen (FMNH 251485) is from Porter County, Indiana, collected in 1993, 19 km W of the IL-IN state line. Because of Kennicott's misidentifications, erroneous locality data, lack of data on the molecular systematics of local ribbon snake populations, and no recent records of *T. sauritus* in northeastern Illinois, this snake is presumed never to have occurred in Cook County.

Virginia valeriae (smooth earth snake). A specimen (USNM 7303-verified) was collected in the mid-1800s by Kennicott, and was cited by Garman (1892). The record was suggested by Smith (1961) to represent a cataloging error. *Virginia valeriae* is a small, secretive woodland species found in southern Illinois.

Crotalus horridus (timber rattlesnake). Kennicott's (1855) inclusion of this snake in his list for Cook County is highly improbable. No suitable habitat existed for this species in northeastern Illinois, and no specimens from the area are known in any museum collection.

Introduced and exotic species

Dancik (1974) summarized 20 turtle species found in Cook County, 13 of which were not native (Table 2). Nature centers are frequent recipients of unwanted exotic amphibians and reptiles, and often such animals are released in forest preserves. Those from tropical climates may survive for short periods if released in spring or summer, but succumb with the onset of cold weather. Exceptions may include the Reeve's turtle (*Chinemys reevesii*), which hibernates at the northern part of its range in China, Japan and Korea (Zhao and Adler, 1993). They have been found in successive years at the Chicago Botanic Garden (Anton, 1992a), though it is unknown if reproduction is occurring. On 21 July 1997, a 2 m, 5 kg Burmese python (*Python molurus*) was found DOR on busy Calumet City street.

DISCUSSION

All habitats in Cook County have been reduced in size, fragmented and isolated through various forms of human development. Wetlands have been eliminated or negatively impacted by alteration of the water table in some areas. Such practices are particularly detrimental to generally immobile amphibians and reptiles.

The discovery of new populations of all amphibian and reptile species in Cook County is possible. State-listed species, and those considered uncommon or rare, were found on FPDCC property. These include *Sistrurus catenatus, Plethodon cinereus,* and *Regina grahami.* However, the county-wide distribution of amphibians and reptiles in Cook County is not expected to increase for most species.

Heavily urbanized preserves having severely degraded habitat, such as those in Indian Boundary, North Branch, and Salt Creek divisions, were not surveyed as thoroughly as those with habitat deemed suitable for rare or state-listed species. These preserves may lack current records of widespread or common species, e.g., *Chelydra serpentina, Chrysemys picta,* and *Thamnophis sirtalis.*

A statewide decline in all amphibians and reptiles was reported by Morris, et al. (1983). There is insufficient data to determine if some species, e.g., *Pseudacris crucifer*, *Rana clamitans*, *Opheodrys vernalis* and *Storeria occipitomaculata* have actually declined, although they were uncommon, rare or absent from localities where they were once easily found.

Seventeen species known historically or previously reported from Cook County were not found during the survey. There is evidence that 3 species (*Clonophis kirtlandii, Necturus*

maculosus and *Ophisaurus attentuatus*) still occur in Cook County. Five species (*Acris crepitans*, *Bufo fowleri*, *Clemmys guttata*, *Hemidactylium scutatum* and *Thamnophis proximus*) are presumed extirpated in Cook County. Three species (*Rana palustris*, *Pituophis melanoleucus*, and *T. sauritus*) probably never occurred on FPDCC property and were erroneously included on FPDCC species lists. The status of six species (*Rana blairi*, *Cnemidophorus sexlineatus*, *Coluber constrictor*, *Elaphe obsoleta*, *Eumeces fasciatus* and *Heterodon platyrhinos*) is unknown.

Old (1850-1930) records of 12 species, some documented by specimens, are believed erroneous due to cataloging errors, mislabeling, or misidentification.

The introduction of non-native or exotic turtle species is another sign of human alteration of amphibian and reptile assemblages in Cook County. Red-eared sliders (*Trachemys scripta*) are the most common introduced species in Cook County. Observations of box turtles (*Terrepene carolina, T. ornata)* and exotic species such as the Chinese Reeve's turtle (*Chinemys reevesii*) and Asian box turtles (*Cuora amboinensis, C. flavomarginata*) have been noted in the last ten years (Anton, 1992a).

The current distribution, relative abundance, and population dynamics of amphibians and reptiles in Cook County is still poorly documented. This is especially true of state listed, rare, or uncommon species. Data collected during this survey may be useful in updating the distribution and status database for amphibians and reptiles in Illinois.

ACKNOWLEDGMENTS

Funding for this study was provided by the U. S. Forest Service and the Conservation Department, Forest Preserve District of Cook County. Database support was provided by C. Phillips (Illinois Natural History Survey). V. Wallach and L. Thomas (Museum of Comparative Zoology-Harvard University), G. Schneider (University of Michigan Museum of Zoology), R. Crombie and A. Wynn (United States National Museum-Smithsonian) verified identities of specimens in their institutions. C. Phillips and two anonymous reviewers made helpful comments on the manuscript.

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Table 1. Status of amphibians and reptiles in the forest preserve district of Cook county, 1995-1997.

SPECIES	No. of Divisions	No. of Preserves	% Frequency	Status
AMPHIBIANS				
Ambystoma laterale	8	22	27	C(LC)
Ambystoma maculatum	3	7	8	R
Ambystoma tigrinum	10	18	22	C
Notophthalmus viridescens	3	6	7	R
Plethodon cinereus	1	1	1	R
Bufo americanus	12	28	35	A
Hyla chrysocelis/versicolor	5	10	12	U(LC)
Pseudacris crucifer	5	10	12	U(LC)
Pseudacris triseriata	11	22	27	A
Rana catesebeiana	12	32	40	A
Rana clamitans	8	11	14	U(LC)
Rana pipiens	9	27	34	A(LC)
Rana sylvatica	3	3	4	R
REPTILES				
Apalone spinifera	6	5	6	R
Chelydra serpentina	9	29	36	A
Chrysemys picta	8	20	25	C
Graptemys geographica	1	1	1	R
Emydoidea blandingi	5	5	6	R(ST)
Sternotherus odoratus	4	6	7	R
Terrepene carolina	1	1	1	R
Trachemys scripta	7	7	9	I(LC)
Clonophis kirtlandii	1	1	1	R
Elaphe vulpina	4	7	9	R(LC)
Lampropeltis triangulum	4	5	6	R
Nerodia sipedon	2	4	5	R(LC)
Opheodrys vernalis	6	5	6	R
Regina grahami	1	1	1	R
Regina septemvittata	1	2	3	R(LC)
Storeria dekayi	12	23	29	A
Storeria occipitomaculata	3	5	6	R
Thamnophis radix	12	20	25	C
Thamnophis sirtalis	11	21	26	A
Sistrurus catenatus	1	2	3	R(SE)

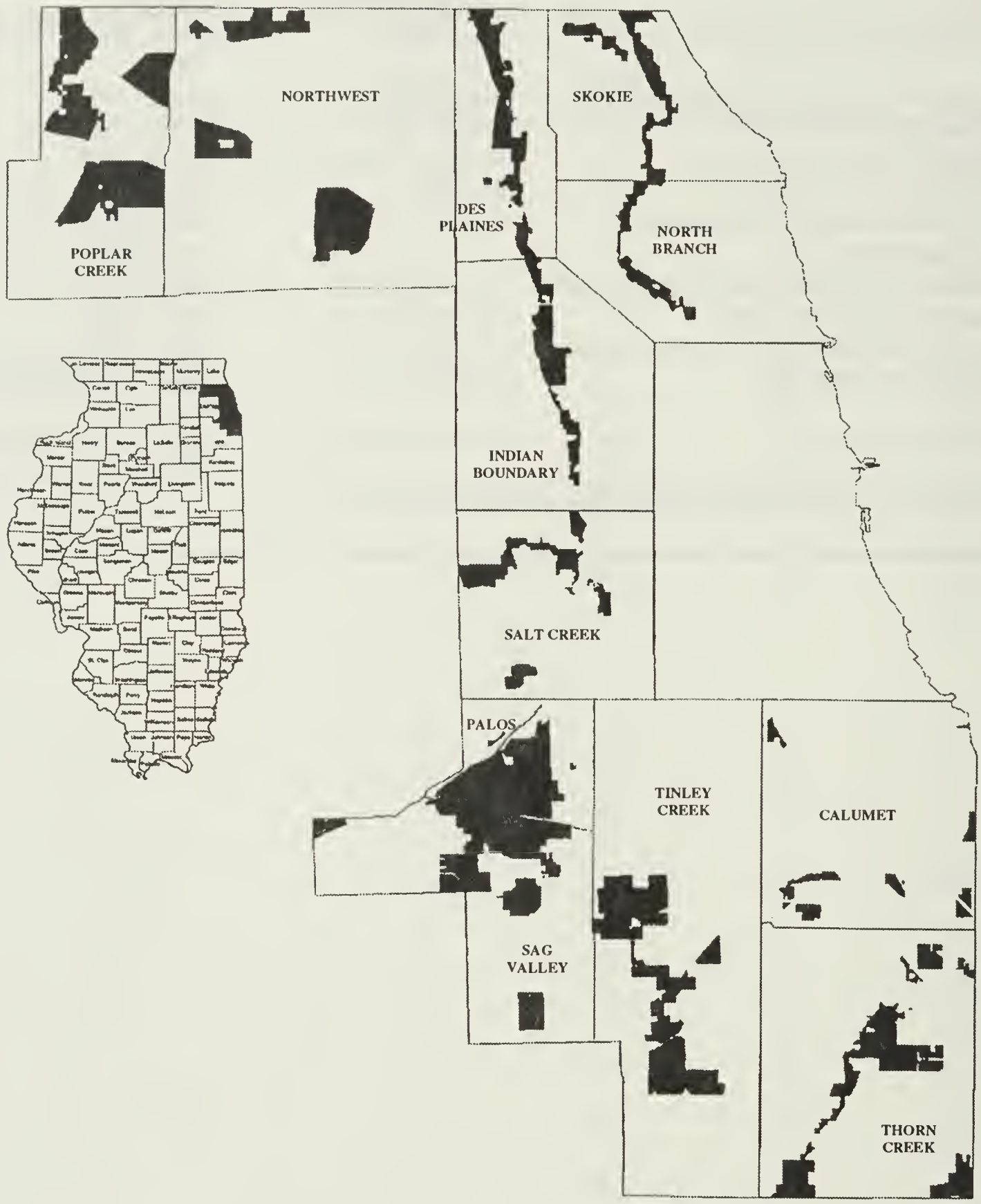
Legend:
A=Abundant, C=Common, I=Introduced species, LC=Locally Common, R=Rare, SE=State Endangered, ST=State Threatened, U=Uncommon
%Frequency=number of preserves in which a species was found divided by 80.

Table 2. Introduced turtles observed in Cook County.

SPECIES	DISTRIBUTION	SOURCE
Reeve's turtle (*Chinemys reevesi*)	Asia/China	Anton, 1992a; Dancik, 1974
Eastern painted turtle (*Chrysemys p. picta*)	Eastern U.S.	Dancik, 1974
Spotted turtle (*Clemmys guttata*)	Eastern U.S.*	Dancik, 1974
Wood turtle (*Clemmys insculpta*)	Northern, Eastern U.S.	Dancik, 1974
Asian box turtles (*Cuora* sp.)	SE Asia	Anton, 1992a
False map turtle complex (*Graptemys pseudogeographica*)	Central U.S.	Dancik, 1974; Ludwig, et al, 1990
Diamondback terrapins (*Malaclemmys terrapin*)	Coastal, SE U.S.	Dancik, 1974
River cooters (*Pseudemys* sp.)	Central, SE U.S.	Dancik, 1974
Neotropical wood turtle (*Rhinoclemmys* sp.)	Central America	Anton, 1992a
Box turtles (*Terrepene* sp.)	Central, E U.S.	Anton, 1992a; Dancik, 1974
Sliders (*Trachemys* sp.)	U.S. and Mexico	Anton, 1992a; Dancik, 1974

*One Illinois population in Will County; State endangered species

Figure 1. Map of the twelve administrative divisions of the Forest Preserve District of Cook County. Shaded areas show land owned and managed by the FPDCC. Inset map shows Cook County's location in Illinois.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 233-241

received 1/4/99
accepted 5/9/99

Dietary Notes on the Red-eared Slider (*Trachemys scripta*) and River Cooter (*Pseudemys concinna*) from Southern Illinois

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ABSTRACT

The primary focus of this study was to ascertain the presence of sexual, seasonal, or ontogenetic differences in the diets of *Trachemys scripta* and *Pseudemys concinna* captured at Round Pond, Gallatin County, Illinois, between 17 May 1994 and 30 August 1995. I collected feces from *T. scripta* and *P. concinna* and separated the contents into eleven dietary categories for *T. scripta* and two for *P. concinna*. I quantified fecal volume by water cc displacement, then described each dietary category by frequency of occurrence, percent volume, and relative percent volume. Juvenile *T. scripta* fecal contents comprised >70% plant matter, while adult males and females had equal proportions of plant and animal matter in their feces. Percent volume and relative percent volume for *T. scripta* fecal samples did not differ between males and females, or between females and juveniles; however, I detected significant differences between males and juveniles and early (May-June) and late (July-August) samples. Overall the diversity of food items in the diet of *T. scripta* was large (Shannon index = 2.50) and the diversity of items expanded from early (Shannon index = 1.19) to late season (Shannon index = 2.72). Females consumed more mollusks than males, and males and females consumed more bryozoans than juveniles. I found Mollusks and bryozoans only in late season samples. *Pseudemys concinna* was herbivorous, specializing on epiphytic filamentous algae of the genera *Cladophora* and *Oedogonium,* with no differences in the frequencies of occurrence between males, females, and juveniles.

Keywords. *Trachemys scripta, Pseudemys concinna*, feeding biology, ontogenetic shift, seasonal shift.

INTRODUCTION

Research on feeding ecology elucidates how an organism meets its bio-energetic demands and allows insight into feeding niches. The primary focus of this study was to

determine if there are any sexual, seasonal, or ontogenetic differences in the diets of *T. scripta* and *P. concinna*. Two types of dietary shift may occur during an organism's life, ontogenetic and seasonal. Ontogenetic dietary shifts have been described for three species of North American freshwater turtles: *Graptemys pseudogeographica* (Moll, 1976), *Chrysemys picta* (Marchand, 1942; Moll, 1977), and *Trachemys scripta* (Minyard, 1947; Cagle, 1950; Clark and Gibbons, 1969; Moll and Legler, 1971; Moll, 1977; Hart, 1983). Juvenile turtles tend to consume small invertebrates and adults meet their metabolic demands by consuming readily available plant material (Marchand, 1942; Parmenter, 1980); further, such size-based shifts in prey size have been described for kinosternid species (Mahmoud, 1968), *Emydura kreftii* (Georges, 1982), and *Hydromedusa maximiliani* (Souza and Shinya, 1998). There are few reports of seasonal dietary shifts. In Belize, Moll (1990) found that *Kinosternon leucostomum* and *K. scorpioides* became more specialized as the season progressed and *Staurotypus triporcatus* became more generalized despite no change in abundance of potential prey; thus, these seasonal dietary shifts remain unexplained. However, the diet of *S. triporcatus* shifted to include the consumption of more *Kinosternon* species as *Kinosternon* species abundance increased during the season. Moll (1990) suggested that *S. triporcatus* is an opportunistic predator of other turtles, encountering and consuming more turtles in the later, drier seasons. First-year *T. scripta* decreased in carnivory through the summer in three ponds located on the Savannah River Plant site, Aiken, South Carolina (Clark and Gibbons, 1969). The investigators hypothesized that insects were either more difficult to capture or less abundant later in the summer, or easily obtainable plant matter met dietary requirements.

The red-eared slider, *Trachemys scripta*, is reported to be an opportunistic omnivore (see Moll and Legler, 1971; Moll, 1990 for reviews) and the river cooter, *Pseudemys concinna*, is mainly herbivorous but juveniles occasionally consume crayfish (Buhlmann and Vaughan, 1991; Marchand, 1942; Thomas et al., 1994). I report on the diets of *T. scripta* and *P. concinna* captured during a long-term mark-recapture program of the latter.

MATERIAL AND METHODS

Study Site

Located about 4 km west of the Ohio River, Round Pond is a relatively small member (ca. 30 ha) of a chain of floodplain lakes in southeastern Gallatin County, Illinois. During annual spring floods these lakes connect, directly or through a system of sloughs, to the Ohio River. Small cabins and trailers occupy the west shoreline, a man-made beach encompasses the southern shore, and the remaining shoreline is bordered by floodplain forest. Several shallow coves less than 1.5 m deep contain numerous basking sites (fallen trees).

Data Collection

I collected data at Round Pond between 17 May 1994 and 30 August 1995. I captured turtles by hand, fyke net, baited hoop trap, dip net, and trammel net and released them onsite. I held approximately fifteen individuals in buckets, in shallow water to retain feces, each night then released them the next day regardless of whether they had defecated. Although fecal samples may be biased because of differential digestion of prey items, most soft tissues may be fully digested leaving little or no trace in the feces, I used them over stomach flushing because 1) *Pseudemys concinna* is listed as state

endangered in Illinois by the Illinois Endangered Species Protection Board of the Illinois Department of Natural Resources, and stomach flushing is occasionally fatal, 2) to maintain comparability between the species, I had to take fecal samples from *Trachemys scripta,* and 3) fecal samples indicate dietary items consumed over a longer period than stomach samples. I sieved individual fecal samples, then preserved them in 10% formalin. I identified the fecal contents under an ocular light or dissecting microscope, depending on size, separated the contents into food categories, and quantified the volume of food categories by water displacement in cc's (Moll and Legler, 1971). I grouped food items into eleven categories: 1) nuts, seeds, and fruits (NSF); 2) leaves, stems, roots, and bark (LSRB); 3) vascular plant material (predominately aquatic grasses); 4) algae; 5) miscellaneous plant material; 6) insects; 7) crustaceans; 8) mollusks; 9) fish; 10) bryozoans; and 11) unidentified material and detritus.

Data Analysis

Dietary categories are presented by:

$$\text{Frequency of Occurrence} = \frac{\text{Number of individuals with diet category x}}{\text{Number of individuals sampled}}$$

$$\text{Percent Volume} = \frac{\Sigma \text{ of the volume (cc) of diet category x over all individuals}}{\Sigma \text{ of the volume (cc) of all diet categories over all individuals}}$$

$$\text{Percent Relative Volume} = \frac{\Sigma \text{ (individual relative volumes) of diet category x}}{\Sigma \text{ of the relative volume of all dietary categories}}$$

where:

$$\text{individual relative volume} = \frac{\text{Percent volume of diet category x for individual n}}{\text{CL of individual n}}$$

I pooled comparison groups for *Trachemys scripta* and *Pseudemys concinna* across years because of small sample sizes, then I partitioned the samples by species into three age/sex categories: males, females and juveniles. I then partitioned the total *T. scripta* data set into early (May-June) and late seasons (July-August). Because of small sample sizes, I could not analyze seasonal variation in the fecal contents of *P. concinna*. I analyzed frequency of occurrence data for sex/age using Kruskal-Wallis H-tests and seasonal data for *T. scripta* using a Mann-Whitney U-test. Because percent volume and relative percent volume data were scaled to one, I used two-sample Kolmogorov-Smirnov cumulative probability tests; however, again due to small sample sizes, I could not analyze *P. concinna* in a similar manner. I set all nominal alpha values at 0.05, and analyzed all data in SPSS for Windows ver. 6.1® or in Microsoft Excel® spreadsheets. I calculated niche breadth using Shannon's H' (Shannon, 1949).

RESULTS

Trachemys scripta

I analyzed a total of 27 fecal samples (13 female, 6 juvenile, and 8 male). I collected seven during May-June (early) and 20 during July-August (late). Plant material made up >40% of the total relative volume of feces in male and female *T. scripta* and >70% in

juveniles; the relative volume of animal matter was approximately the same for sexes (Table 1). There was no significant difference in the frequency of occurrence of dietary categories among sex/age grouping ($\chi^2 = 0.048$, d.f. = 2, $p = 0.9763$). Juvenile percent volume and percent relative volume of fecal contents were significantly different from those of males (percent volume: $D_{max} = 0.666$, $0.05 > p > 0.01$, $n_1 = 11$, $n_2 = 11$; percent relative volume: $D_{max} = 0.679$, $0.05>p>0.01$, $n_1 = 11$, $n_2 = 11$) but not from those of females (percent volume: $D_{max} = 0.560$, $p > 0.05$, $n_1 = 11$, $n_2 = 11$; percent relative volume: $D_{max} = 0.467$, $p > 0.05$, $n_1 = 11$, $n_2 = 11$). The higher percent relative volume of LSRB markedly increased the total percent relative volume of plant material in juvenile feces. Juvenile feces never contained bryozoans. Male percent volume and percent relative volume of fecal contents did not differ significantly from those of females (percent volume: $D_{max} = 0.166$, $p > 0.05$, $n_1 = 11$, $n_2 = 11$; percent relative volume: $D_{max} = 0.185$, $p > 0.05$, $n_1 = 11$, $n_2 = 11$); however, there were a few noteworthy qualitative differences. Bryozoans and aquatic grasses predominated in the feces of males. Female feces contained slightly more bryozoans and mollusks, and lesser amounts of aquatic grasses (Table 1).

The niche breadth of *T. scripta* at Round Pond was 2.5 and expanded from early (H'=1.19) to late season (H'=2.72). The expansion was accompanied by a non-significant difference in frequency of occurrence of dietary items ($U = 34$, $n_1 = 11$, $n_2 = 11$, $z = -1.759$, $p = 0.0785$), and a significant seasonal difference in percent volume ($D_{max} = 0.8366$, $0.01> p > 0.001$, $n_1 = 11$, $n_2 = 11$) and relative percent volume ($D_{max} = 0.827$, $0.01> p > 0.001$, $n_1 = 11$, $n_2 = 11$). Early in the season, feces contained more LSRB, and later, more bryozoans and aquatic grasses (Table 1).

Pseudemys concinna

I collected 16 fecal samples, four males, six females, and six juveniles. Because it was impossible to separate algal species from each other and from *Sagitaria* for volumetric analyses, I could only use two categories, aquatic grasses, and *Sagitaria* and algae (Lower Plants) in the analysis. I expressed data as frequency of occurrence and percent volume. Lower plants comprised 98% of the fecal volume of *P. concinna* sampled (Table 2). Filamentous algae of the genera *Cladophora* and *Oedogonium* predominated the samples (Table 2). The numerous species of unicellular algae and diatoms present, though probably eaten incidentally along with algal mats, may have nutritive value. Feces of only two juveniles and one female contained aquatic grasses (Table 2). Frequency of occurrence data did not differ significantly ($\chi^2 = 0.4795$, d.f. = 2, $p = 0.7868$) among age/sex categories and *P. concinna*'s niche breadth was 0.14.

DISCUSSION

Trachemys scripta

Data for adults are somewhat different from those of other reports in that both sexes consumed approximately equal amounts of plant and animal matter and the diets of juveniles contained over 70% plant matter. Illinois specimens collected in July contained equal amounts of fish and plant matter (Smith, 1961). Cahn (1937) reported that Illinois *T. scripta* consumed amphibians, mollusks, crustaceans, insects, fish, and plant material. In Reelfoot Lake, Tennessee, *T. scripta* stomachs contained mostly plant matter (Parker, 1939). Range-wide, much of the data supporting *T. scripta*'s carnivorous habits are

based on captive individuals (Carr, 1952). Diets of adults from Florida were reported to consist of 89% plant matter and 9% animal matter and diets of immatures 30% plant matter and 52% animal matter (Marchand, 1942). In the Neotropics *T. scripta* adults and juveniles consumed similar proportions of plant matter (Moll and Legler, 1971).

Juveniles are reported as carnivorous (reviewed by Moll and Legler, 1971). However, at Round Pond, feces of juveniles lacked bryozoans and fish but contained large amounts of nuts, seeds and fruits, and insects, as Parker (1939) reported at Reelfoot Lake, Tennessee. Juvenile *T. scripta* on the Savannah River Site, Aiken, South Carolina, had a more varied and carnivorous diet than adults. Moreover carnivory, specifically insectivory, decreased in first-year turtles during the summer (Clark and Gibbons, 1969). They attributed the decrease in insectivory to a decreased abundance of insects, greater difficulty in obtaining insects later in the season, or the satisfaction of nutritional requirements with plant matter alone (Clark and Gibbons, 1969). A Louisiana population exhibited a gradual shift from carnivory to herbivory as individual size increased, and this dietary shift with size paralleled a habitat shift related to body size (Hart, 1983). Because of sample size limitations the effects, if any, of season on the diet of Round Pond *T. scripta* age/sex categories remain unresolved. Moll and Legler (1971) found a similar proportion of insect matter (16.3%) and a lack of fish in the stomachs of neotropical *T. scripta.* Moll (1990) found juvenile *T. scripta* at Chan Chen, Belize, to be almost entirely insectivorous.

Although diets of adult males and females in Illinois were not significantly different, there are some apparent qualitative differences. The feces of only females contained mollusks and then only after the nesting season (July and August). In contrast, in the Neotropics, Moll and Legler (1971) found consumption of gastropods greatest before nesting. They hypothesized that females in this way acquired calcium for egg production. Females in temperate regions may lack the time required to acquire calcium before nesting. Instead, they may mobilize calcium from their skeletons, then replace the calcium when mollusks are at higher abundance.

The proportion of leaves, stems, roots and bark (LSRB), algae, and bryozoans consumed varied between seasons. The increased consumption of bryozoans later in the year may indicate anticipated energetic demands of hibernation. Early in the year, LSRB composed 74% of the fecal volume, whereas later LSRB accounted for 9% of the fecal volume. Although a population of *T. s. elegans* inhabiting a roadside ditch was reported to subsist on leaves alone (Cagle, 1950), the majority of the LSRB samples in this study consisted of roots and bark. Because bryozoans and algae found in the feces were epiphytic, this dietary category might be considered incidentally consumed; however, when bryozoan intake was highest, proportional intake of LSRB was lowest, suggesting the more credible alternative that *T. scripta* at Round Pond cue on substrates such as submerged logs and rocks even when bryozoan and algal epiphytes are not at peak abundance. My data indicate dietary shifts; however, further analysis and more data need to be collected on the periodicity, timing and composition of the shifts.

Pseudemys concinna

At Round Pond, *P. concinna* specialized on filamentous algae, which also predominated in the diets of cooter populations in Florida (Lagueux et al., 1995), Missouri (Thomas et

al., 1994), and North Carolina (Brimley, 1943; in Ernst et al., 1994). New River, West Virginia, cooters consumed filamentous algae until macrophytes appeared in the spring (Buhlmann and Vaughan, 1991). Studies throughout the range of *P. concinna* show it to be chiefly herbivorous (Allen, 1938; Parker, 1939; Marchand, 1942; and Lagueux et al., 1995) and are supported by the finding of symbiotic cellulolytic bacteria in the gut by Thomas et al. (1994). Symbiotic microflora have also been found in other herbivorous and omnivorous species: *Chelonia mydas* (Bjorndal, 1979), *Gopherus polyphemus* (Bjorndal, 1987), and *Trachemys scripta* (Bjorndal and Bolten, 1990). However, reports contradicting the typical herbivorous diet of *P. concinna* exist. Illinois *P. concinna* were reported as largely carnivorous (Cahn, 1937) and in the New River, West Virginia, adults occasionally consumed crayfish, whereas juveniles were omnivorous (Buhlmann and Vaughan, 1991).

ACKNOWLEDGMENTS

This project was completed in partial fulfillment of the Master of Science degree at Eastern Illinois University (E.I.U.), Charleston, Illinois. Funding for this research was provided by the Illinois Endangered Species Protection Board, E.I.U. Council on Faculty Research, E.I.U. Honors Program Undergraduate Research Award, the Linnaeus Fund of the Chelonian Research Foundation, and the E.I.U. Graduate Summer Research Assistantship Award. I thank L.E. Bryant and J.R. Dreslik for their assistance in the field; E.O. Moll for serving as mentor, advisor, colleague and friend; K.C. Kruse, R.U. Fischer and E.K. Bollinger for serving as thesis committee members; C. Pederson and J. Ebinger for aid with plant and algal identification and C.A. Phillips, L.M. Page, J.D. Litzgus, J. Walk and two anonymous reviewers for their comprehensive suggestions toward the improvement of this manuscript.

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Table 1: Dietary items taken from fecal samples of *Trachemys scripta* captured at Round Pond, Gallatin County, Illinois during the summers of 1994 and 1995. Data are expressed as frequency of occurrence, percent relative volume (in brackets) and percent volume (in parentheses). LSRB = Leaves, stems, roots, and bark.

	Males (n = 8)			Females (n = 13)			Juveniles (n = 6)			May – June (n = 7)			July – August (n = 20)		
Plant Material		**[0.50]**	**(0.50)**		**[0.44]**	**(0.42)**		**[0.72]**	**(0.72)**		**[0.93]**	**(0.93)**		**[0.41]**	**(0.40)**
Nuts, Seeds Fruits	0.00	[0.00]	(0.00)	0.15	[0.03]	(0.02)	0.33	[0.10]	(0.10)	0.00	[0.00]	(0.00)	0.20	[0.03]	(0.02)
L,S,R,B	0.63	[0.13]	(0.13)	0.38	[0.16]	(0.14)	0.67	[0.52]	(0.52)	0.71	[0.74]	(0.68)	0.45	[0.10]	(0.08)
Higher Plant Material	0.63	[0.29]	(0.28)	0.23	[0.12]	(0.14)	0.17	[0.06]	(0.06)	0.00	[0.01]	(0.01)	0.45	[0.19]	(0.20)
Algae	0.38	[0.08]	(0.09)	0.31	[0.05]	(0.06)	0.33	[0.04]	(0.04)	0.43	[0.18]	(0.24)	0.30	[0.04]	(0.05)
Misc. Plant Material	0.13	[0.003]	(0.003)	0.08	[0.08]	(0.06)	0.00	[0.00]	(0.00)	0.00	[0.00]	(0.00)	0.10	[0.06]	(0.05)
Animal Material		**[0.48]**	**(0.47)**		**[0.56]**	**(0.59)**		**[0.11]**	**(0.11)**		**[0.06]**	**(0.07)**		**[0.57]**	**(0.59)**
Insects	0.50	[0.19]	(0.002)	0.69	[0.03]	(0.03)	0.83	[0.10]	(0.10)	0.57	[0.06]	(0.06)	0.70	[0.02]	(0.02)
Crustaceans	0.00	[0.00]	(0.00)	0.00	[0.00]	(0.00)	0.17	[0.01]	(0.01)	0.00	[0.00]	(0.00)	0.05	[$1x10^{-5}$]	($5x10^{-4}$)
Mollusks	0.00	[0.00]	(0.00)	0.15	[0.05]	(0.06)	0.17	[0.004]	(0.004)	0.00	[0.00]	(0.00)	0.15	[0.04]	(0.05)
Fish	0.63	[0.03]	(0.03)	0.46	[0.02]	(0.02)	0.00	[0.00]	(0.00)	0.14	[0.01]	(0.01)	0.50	[0.02]	(0.02)
Bryozoans	0.25	[0.45]	(0.44)	0.31	[0.46]	(0.48)	0.00	[0.00]	(0.00)	0.00	[0.00]	(0.00)	0.30	[0.49]	(0.50)
Unidentified/Detritus	**0.13**	**[0.02]**	**(0.03)**	**0.00**	**[0.00]**	**(0.00)**	**0.33**	**[0.17]**	**(0.17)**	**0.14**	**[0.01]**	**(0.004)**	**0.10**	**[0.02]**	**(0.02)**

Table 2: Frequency of occurrence and percentage volume (in brackets) of dietary items found in 16 *Pseudemys concinna* fecal samples from specimens taken from Round Pond, Gallatin County, Illinois. Percentage volume encompasses only the categories of aquatic grasses and *Sagitaria* and algae. The female category includes both immature and mature females.

	Aquatic Grasses		*Sagitaria* and Algae			
	Poaceae		*Oedogonium*	*Sagitaria*	*Cladophora*	
Male (n=4)	0.00	[0.00]	0.75	0.00	0.75	[1.00]
Female (n=6)	0.17	[0.02]	0.67	0.50	1.00	[0.98]
Juvenile (n=6)	0.33	[0.03]	0.67	0.17	1.00	[0.97]
Total	0.19	[0.02]	0.69	0.25	0.94	[0.98]

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 243-245

received 9/29/98
accepted 12/4/98

Newly Reported Snake Hosts for Two Ochetosomatid Digeneans in Illinois

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ABSTRACT

The oral cavity of single specimens of Nerodia erythrogaster, Nerodia rhombifer and Lampropeltis getula from Jackson County, Illinois were examined for the presence of helminths. Ochetosoma aniarum was detected in Nerodia erythrogaster and Nerodia rhombifer and Ochetosoma elongatum in Lampropeltis getula. This extends the host spectrum record of ochetosomatid digeneans in this state.

INTRODUCTION

Several species of ochetosomatid digeneans in snakes of Illinois have been reported over the past 28 years. Dyer (1970) reported *Ochetosoma elongatum* (Pratt, 1903) in the lungs of the eastern hognose snake, *Heterodon platirhinos* Laterille, 1801 from Williamson County, *Ochetosoma kansense* (Crow, 1913) in the mouth of the gray rat snake, *Elaphe obsoleta spiloides* (Duméril, Bibron and Duméril, 1854) and in the esophagus of *Lampropeltis* sp. also from Williamson County, and *Ochetosoma ellipticum* (Pratt, 1903) in the mouth of *H. platirhinos* from Jackson County. Dyer and McNair (1974) reported *O. elongatum* in the mouth, esophagus and stomach of *H. platirhinos* and *O. kansense* in the mouth of the common kingsnake, *Lampropeltis getula* (Linnaeus, 1766) from Jackson County. Dyer and Ballard (1989) reported *O. elongatum* in the oral cavity of *H. platirhinos*, *O. kansense* in the oral cavity of *L. getula* and *O. ellipticum* in the oral cavity of the plainbelly water snake, *Nerodia erythrogaster* (Forster, 1771), the diamond-back water snake, *Nerodia rhombifer* (Hallowell, 1852) and the mouth of the racer, *Coluber constrictor* Linnaeus, 1758 from Johnston and Jackson Counties. Later, Dyer and Ballard (1991) reported *Ochetosoma aniarum* (Leidy, 1891) in the oral cavity of the Mississippi green water snake, *Nerodia cyclopion* (Duméril, Bibron and Duméril, 1854) from Union County. The present report adds to our knowledge of ochetosomatid digeneans in snakes of Illinois.

MATERIALS AND METHODS

Single specimens of *Nerodia rhombifer*, *Nerodia erythrogaster* and *Lampropeltis getula* were captured in Jackson County, Illinois during May 1988. The oral cavity of each snake was examined within a few hours of capture for the presence of parasites. Parasites were removed with a cotton swab saturated with tap water and then transferred to a con-

tainer of tap water where egg release was observed. Five digenean specimens were removed from *N. rhombifer*, three from *N. erythrogaster*, and four from *L. getula.* After all or most of the eggs were released from the uterus, each digenean was trasferred to a slide and a crystal of urethane added to the water to induce relaxation. A coverslip was then added and the specimen fixed in AFA (alcohol-formalin-acetic acid), stained with Harris' hematoxylin, dehydrated, cleared in beechwood creosote and mounted in Canada balsam.

RESULTS AND DISCUSSION

The five specimens from *Nerodia rhombifer* and the three specimens from *Nerodia erythrogaster* were identified as *Ochetosoma aniarum* (Leidy, 1891). *O. aniarum* was first described by Leidy (1891) under the name *Distomum aniarum.* Dubois and Mahon (1959) listed *Renifer acetabularis* (Crow, 1913), *Renifer natricis* (MacCallum, 1921), *Renifer texanus* (Harwood, 1932), *Renifer orula* (Talbot, 1934), and *Renifer wardi* (Byrd, 1936) as synonyms of *O. aniarum* and provided a key for the differentiation of the various species of *Ochetosoma.* According to the key given by Dubois and Mahon (1959), *O. aniarum* may be differentiated from all other species of *Ochetosoma* according to the position of the genital pore which is even with the oral sucker, the distribution of the vitelline glands which are divided into two groups of follicles (pre-and postacetabular) and by a ventral sucker which is 1.5 time longer than the oral sucker.

The four specimens from *Lampropeltis getula* were identified as *Ochetosoma elongatum* (Pratt, 1903). *O. elongatum* was first decribed by Pratt (1903) under the name *Renifer elongatus*. Dubois and Mahon (1959) listed *Lechriorchis validus* (Nicoll, 1911), *Lechriorchis inermis* (Lebour, 1913), *Lechriorchis abduscens* (Byrd and Denton, 1938), *Renifer magnus* (Byrd and Denton, 1938), *Neorenifer heterodontis* (Byrd and Denton, 1938), *Neorenifer drymarchon* (Bryd and Denton, 1938), *Renifer grandispinus* (and *Renifer longispinus*, pl. 111, fig. 3 *lapsus calami*) (Caballero, 1938), as synonyms of *O. elongatum*. According to the key proposed by Dubois and Mahon (1959), *O. elongatum* may be differntiated from other known species of *Ochetosoma* by the location of the genital pore which is medio-lateral (found either closer to the mid-line than to the body margin or equidistant between the two), between the level of the attachment of the prepharynx and the bifurcation of the intestine, such that the cirrus pouch is orientated obliquely, and by the distribution of the vitelline glands which are distributed in small groups (6-12 on each side) in an area beginning midway between the gut bifurcation and the acetabulum and ending at the level of the testes or slightly behind.

In a study of the differences in measurements of morphological features between live and fixed specimens of *Ochetosoma*, Dronen and Guidry (1977) presented data suggesting that the absolute dimensions of various body parts are inadequate criteria for differentiating species of *Ochetosoma.* This may be because fixation techniques are not standardized and some specimens have been described from live material and other from fixed material. Identifications in the present report are based on the criteria used by Brooks (1979) in differentiating specimens of *Ochetosoma*, namely: the vitelline configuration, the sucker ratio, the location of the genital pore, the posterior extent of the cirrus sac, and the amount of glandulation inside the cirrus sac.

The present report of *Ochetosoma aniarum* in *Nerodia rhombifer* and *Nerodia erythrogaster* and *Ochetosoma elongatum* in *Lampropeltis getula* adds to our knowledge of the host spectrum of ochetosomatid digeneans in snakes of Illinois. Voucher specimens have been depoited in the United States National Parasite Collection (USNPC), U. S. Department of Agriculture, Beltsville, Maryland and designated as No. 88231 for *O. aniarum* in *N. rhombifera*, No. 88232 for *O. aniarum* in *N. erythrogaster* and No. 88230 for *O. elongatum* in *L. getula.*

ACKNOWLEDGMENTS

The author thanks Scott Ballard for providing the snakes used in the study.

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 247-256

received 10/28/98
accepted 3/6/99

Raccoon (*Procyon lotor*) Survival in West-Central Illinois

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ABSTRACT

Raccoons (*Procyon lotor*) were livecaptured (n = 347) during 1989-93 on an area open to hunting and trapping in west-central Illinois to determine the effects of harvest, body condition, breeding condition and exposure to disease on survival. Survival was determined from radiotelemetry (n = 45) and analyzed using Kaplan-Meier survival estimates (S = 0.74). Human-related activities accounted for 81% of mortality (68% from harvest and 13% from vehicles) on the study area. Age groups were similar in susceptibility to harvest. Survival curves were not different between male and female raccoons. Adult female raccoons had a higher condition index than female juveniles or yearlings ($P < 0.001$). Body condition index was not related to survival or a cause of death in either males or females. Eighty-five percent of adult and 50% of yearling female raccoons bred during the year they were captured. Of 229 raccoons tested for exposure to diseases, 73% tested seropositive for at least one of the following: distemper (28%), leptospira (50%), toxoplasma (57%) and pseudorabies virus (22%). We found no difference in survival between raccoons testing positive and those testing negative for at least one disease. Mortality on the study area was primarily related to human, not physiological factors, such as body condition, disease, or breeding condition.

INTRODUCTION

Raccoons are abundant in Illinois, in part, because of omnivorous food habits, willingness to make a den in almost any natural or artificial cavity and an adaptability to urban conditions (Hoffmeister 1989). Because of the prevalence of legal harvesting of raccoons, many studies of mortality concentrated on harvested populations (Glueck et al. 1988, Clark et al. 1989, Brown et al. 1990, Hasbrouck et al. 1992, Rolley and Lehman 1992).

Several factors have been related to mortality in raccoons, including hunting, trapping, vehicle collisions and disease (Glueck et al. 1988, Clark et al. 1989, Brown et al. 1990, Hasbrouck et al. 1992, Rolley and Lehman 1992). In addition to population management issues, concern over the raccoon as a vector for disease transmission has increased as more humans, pets and livestock come into contact with abundant raccoon populations (Brown et al. 1990, Fischman et al. 1992, Torrence et al. 1992, Hill et al. 1993, Roscoe 1993).

Hasbrouck et al. (1992) reported differential mortality between sexes of adult raccoons and among age groups. Juvenile survival is important in the demography of raccoon populations (Sanderson and Hubert 1981, Hasbrouck et al. 1992, Judson et al. 1994). Juvenile raccoons could suffer higher mortality due to increased movements during that period of life (Hasbrouck et al. 1992). Johnson (1970) noted that the highest mortality in Alabama raccoons was during the first 2 years of life.

Factors which reduce longevity will, in turn, affect the reproductive capacity and, therefore, population density. In addition to reproductive costs in relation to pregnancy and lactation (Millar 1975, Millar 1977, Gittleman and Thompson 1988, Oftedal and Gittleman 1989), breeding condition and corresponding behavior of female raccoons could increase their vulnerability to various causes of mortality.

We studied raccoon survival in a population open to hunting and trapping. The objectives of the study were to determine the survival rates (based on radiotelemetry) of raccoons and identify sources of mortality for harvested populations. We also analyzed raccoon survival as influenced by disease, body condition and female breeding status.

METHODS

Raccoons were live-captured between fall 1989 and fall 1993 on a 2,310 ha area in Brown County, west-central Illinois. The study area consisted of row crops (mainly corn and soybeans) (59%), pasture (15%), shrub and cut-over forest (25%) and a few small ponds (<1%). The study area was open to hunting and trapping each fall. Minimum raccoon density on the area was estimated at 4.5 raccoons/km^2 (Nixon et al. 1995).

A total of 347 raccoons were live-trapped during April-June and August-November each year. Live-traps were baited with an egg and sardines and opened for 10 to 30 days on each site per season. Raccoons were sedated using Ketaset or Telozol, sexed, weighed and field aged, examined for external parasites, bled using heart puncture (5-10 ml) and measured for length. A fecal sample was taken and a premolar extracted for aging using tooth cementum annuli (Grau et al. 1970). Raccoons were eartagged and released at the trap site. Raccoons < 12 months of age were considered juveniles, those 12 to 23 months old were classified as yearlings, and raccoons ≥ 2 years of age were considered adults. Breeding status of females was classified as breeding (nursing or pregnant) or not breeding.

Radio transmitters equipped with a mortality-sensitive switch were placed on 21 male and 24 female raccoons, including 17 adults, 13 yearlings, and 15 juveniles. Radiocol-

lared raccoons were located at least once a week throughout the study using two truck-mounted 8-element yagi antennas aligned in a null configuration.

Blood samples were taken from all raccoons examined (n = 347) to detect the exposure of the animals to specific diseases, including canine distemper virus, leptospira *(Leptospira* sp.), toxoplasma (*Toxoplasma gondii*) and pseudorabies virus (suid herpes virus 1). Sera were separated and immediately frozen. Tests for leptospira antibodies and pseudorabies virus was performed at the University of Illinois College of Veterinary Medicine, Urbana, Illinois. Canine distemper testing was conducted at the New York State Animal Diagnostic Laboratory, Ithica, New York, and toxoplasma testing was performed at the USDA laboratory in Bethesda, Maryland (Nixon et al. 1995).

We calculated a condition index for each raccoon during each trapping period using the formula body mass/(body length)^3 x 100,000 after Hasbrouck et al. (1992). For survival analyses, physical condition was classified as either above or below the median of the condition index for each age group of radio-collared raccoons. All other associations with body condition (sex, female breeding status) used all live-trapped animals for which body length and weight also were available. Dead raccoons were necropsied on site or at the University of Illinois School of Veterinary Medicine to determine cause of death.

The survival analysis, using only radio-collared raccoons, was calculated using the staggered-entry design of the Kaplan-Meier product limit estimator (Kaplan and Meier 1958, Pollock et al. 1989) and the log-rank test for homogeneity between groups. To calculate age specific mortality and the average expected years of life upon reaching a given age, we constructed a life table using the cohort born in 1990 for which we had the most data (Begon and Mortimer 1986, Downing 1980). Only those raccoons captured or known to be alive at the beginning of each year were used in the life table analysis.

Analysis of variance was used to compare condition indices between sexes, age groups, and years for all live-trapped raccoons. Chi-square tests were used to separately analyze each variable (disease, cause of death and breeding status).

RESULTS

Of 347 raccoons (138 females and 209 males) captured during this study, 117 were juveniles, 115 were yearlings, and 115 were adults when first captured. The ultimate fate was known for 80% of radio-collared raccoons (20% had a lost signal, battery died, etc.) and 31% of non-radioed raccoons (69% were never captured or reported again).

Survival

There was no difference in Kaplan-Meier survival distributions between yearling and adult radio-collared raccoons (X^2 = 0.04, df = 1, P = 0.86). Mean annual survival (SE) for the combined yearling and adult radio-collared raccoons was 0.74 ± 0.07 SE. There was no significant difference in survival between males and females (X^2 = 0.22, df = 1, P = 0.67) (Fig.1). Survival estimates were not calculated for juvenile raccoons since the spring trapping session did not sample the very young, and those not surviving to the fall trapping session were unavailable for capture.

Fourteen (31%) of radio-collared raccoons and 70 (23%) of non-radioed raccoons were taken by hunters or trappers. The 14 radio-collared raccoons which were harvested (hunted or trapped) during the study consisted of 6 females and 8 males, of which 2 were shot out of season. For radio-collared and non-radioed raccoons combined, harvest mortality accounted for 74% of all known deaths of non-radioed raccoons and 48% of radio-collared (Table 1). Susceptibility to harvest was similar ($X^2 = 0.51$, df = 2, P = 0.78) between age groups for radioed and non-radioed raccoons.

Based on tooth age, the maximum age for females was 9 years old ($\bar{x}$ = 4.0 years ± 1.6 SD, n = 50) and 7 years old for males ($\bar{x}$ = 3.3 years ± 1.4 SD, n = 65). At the time of capture, only 5% of all raccoons were ≥ 4 years of age. Of the 6 causes of death recorded on the study area (Table 1), hunted raccoons had the lowest average age (2.0 years ± 1.41 SD). The mean age for all raccoons (n = 124) which were known to have died during the study period (Table 1) was 2.4 years ± 1.66 SD.

Disease

Of 229 raccoons tested for exposure to one or more of 4 diseases, 168 (73%) tested positive for at least one disease. Twenty-eight percent of those tested for distemper were seropositive, 50% for leptospira, 57% for toxoplasma and 22% for pseudorabies virus. Forty-one percent (n = 93) of tested raccoons showed exposure to 2 or more diseases. The mean age of raccoons (both sexes) killed by disease (Table 1) was 3.0 years (n = 15). For radio-collared raccoons, we found no difference in survival distributions between raccoons testing positive and those testing negative for at least one disease ($X^2 = 0.90$, df = 1, P = 0.37).

Of the 168 raccoons tested positive for at least one disease at the time of capture, 51 died from various causes, including disease, and were later recovered. Thirty-four of the 51 were killed by hunters or trappers, 8 were killed by vehicles, 6 died from disease, 2 were killed by dogs and one died from an unknown cause. An additional 9 raccoons died from disease, of which 4 tested negative at the time of capture and 5 were not tested for disease exposure (Table 1).

Body condition

Survival of radio-collared raccoons was not related to body condition index ($X^2 = 0.57$, df = 1, P = 0.47). For radioed and non-radioed raccoons combined, body condition did not differ among years within any age group (F = 0.92; df = 7, 240; P = 0.49). There were no significant differences in condition indices between male and female raccoons within any age group (F = 1.61; df = 4, 243; P = 0.17). Monthly condition indices of females were similar (F = 0.97; df = 6, 62; P = 0.45), while condition indices of males increased from April through November (F = 4.84; df = 6, 88; P < 0.001) (Fig. 2). Adult female raccoons had a higher mean condition index than female yearlings or juveniles (F = 4.81; df = 2, 102; P = 0.01). Regardless of age or sex, body condition was not different among causes of death in raccoons (F = 0.19; df = 5, 79; P = 0.97). Condition indices were similar between animals which tested positive or negative for exposure to disease (t = -0.18, df = 224, P = 0.86).

Female breeding

Yearling female breeding averaged 46% for 1990-1993 and adults averaged 87% breeding. Sample sizes were too small to detect a difference in survival based on breeding status. Female breeding status was not related to body condition ($t = 0.49$, $df = 73$, $P = 0.62$).

DISCUSSION

As in other studies (Johnson 1970, Kaufmann 1982, Hasbrouck et al. 1992), human activities were the primary cause of mortality in raccoons in the west-central Illinois study area. Human-related mortality (harvest and roadkills) accounted for 81% of deaths, similar to the 88% of all deaths reported for Iowa raccoons (Clark et al. 1989). The annual survival rate for raccoons at least one year old (0.74) was higher compared to yearling (0.51) and adult (0.53) raccoons in Iowa (Hasbrouck et al. 1992). The lower survival in Iowa might be accounted for by the increased harvest rate imposed as part of their study.

Juvenile vulnerability to harvest has been noted for various furbearers (Pils et al. 1981, Payne 1984, Clark et al. 1989). Sanderson and Hubert (1981) reported that juveniles made up 68% of harvested raccoons in Illinois, but in our study, juveniles accounted for only 30% of those harvested.

Female raccoons have been shown to have smaller home ranges than males (Fritzell 1978). Nixon et al. (1995) reported that breeding females reduced the range of their daily movements, remaining closer to the natal den in spring and summer. Restricting their movements could reduce the female's chance of being killed by a vehicle, or encountering a predator, hunter or trap (Kaufmann 1982, Hasbrouck et al. 1992). We did not find a difference in survival between sexes, possibly due to small sample sizes.

Although adult female raccoons had a higher condition index than younger females, it did not appear to be related to breeding success. Female breeding rates, based on breeding status at the time of capture, were similar to those reported by Fritzell et al. (1985) for Illinois and Missouri and by Clark et al. (1989) in Iowa.

Certain diseases are more likely to affect survival than others, but our analysis was unable to partition the cumulative effect of chronic disease exposure on the survival risk of individual raccoons. Leptospira do not usually kill their host outright, but may result in a chronic long-term health risk (Shotts 1981). The data suggest that disease did not influence survival given that only 4% of those testing positive to chronic disease exposure had later died from disease. Even if we assume that the seropositive animals would eventually die from disease, most individuals lived long enough to produce offspring for several years, as indicated by the breeding rate and high average age of females. In addition, we found no significant relationship between a condition index and subsequent survival of raccoons. Hasbrouck (et al. 1992) also found no relationship between survival and condition in Iowa raccoons.

Our study, and others, show that raccoons are vulnerable to a wide array of hazards of which have variable impact on survival. Hunting and trapping were the major causes of

mortality in this study. The annual survival of raccoons will not likely be the result of one factor alone, but rather a combination of different environmental conditions and behavioral components (Kaufmann 1982, Sanderson 1987).

ACKNOWLEDGMENTS

We are grateful to J. Seets, M. Mitchell, G. R. Lang and T. Rothering for assistance in this study. We also thank numerous landowners for allowing access to the study areas. R. D. Bluett, G. F. Hubert, Jr., G. C. Sanderson, and R. E. Warner reviewed the manuscript. This study was supported by the Federal Aid in Wildlife Restoration Project W-104-R, the Illinois Department of Natural Resources, the U.S. Fish and Wildlife Service and the Illinois Natural History Survey.

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Table 1. Mean age at time of death by cause of death for raccoons in west-central Illinois 1989-93.

Cause	Mean	SD	N
Dog	4.2[a]	1.93	5
Disease	3.0	1.27	15
Road	2.7	2.20	17
Trapping	2.7	1.80	24
Misc[b]	2.6	0.54	3
Hunting	2.0	1.41	60
Total	2.4	1.66	124

[a] Significantly different from other causes ($P < 0.05$)

[b] 1 poisoned, 1 electrocuted and 1 unknown cause

Figure 1. Kaplan-Meier survival curves of radio-collared male (N = 21) and female (N = 24) raccoons in west-central Illinois 1989-93.

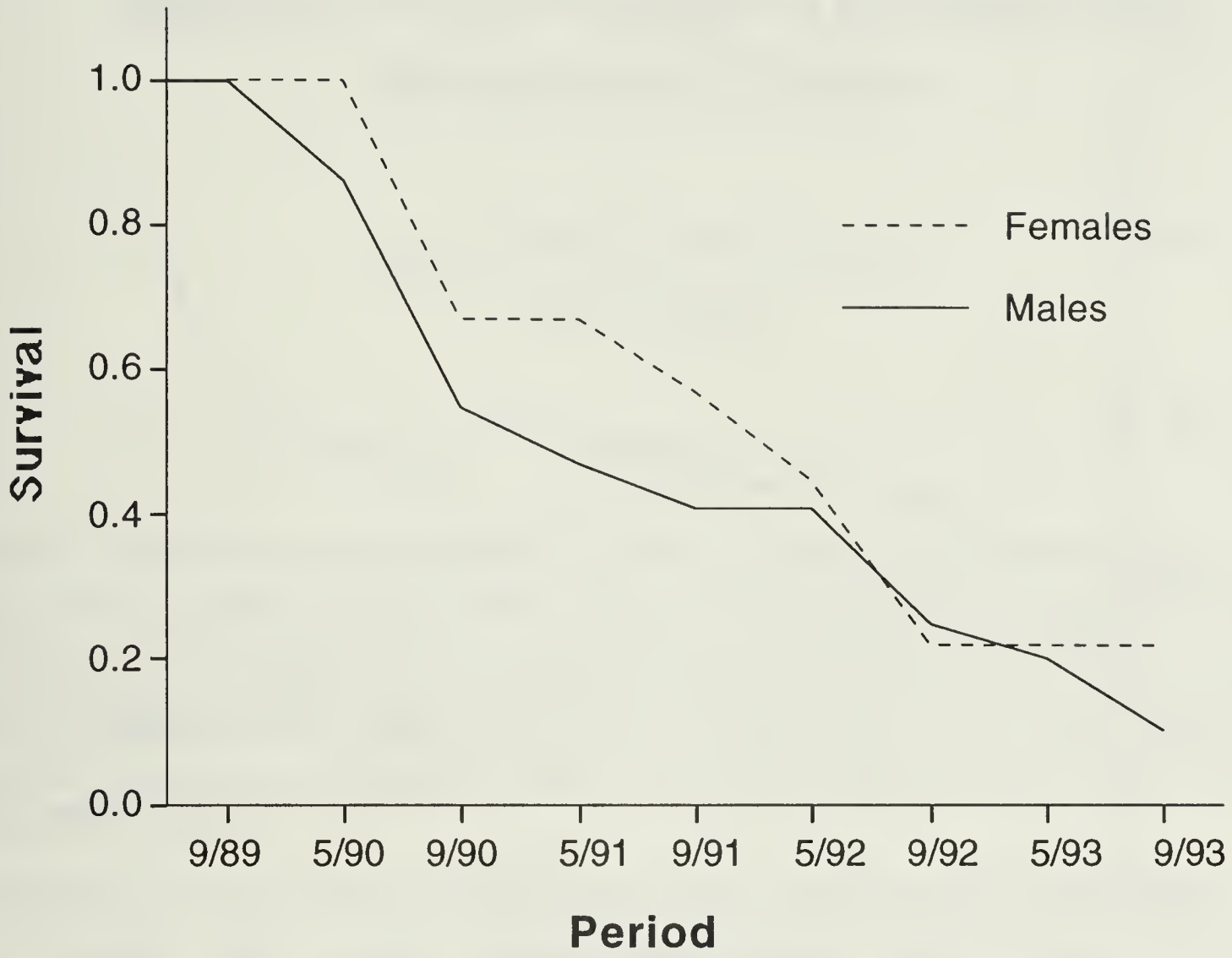
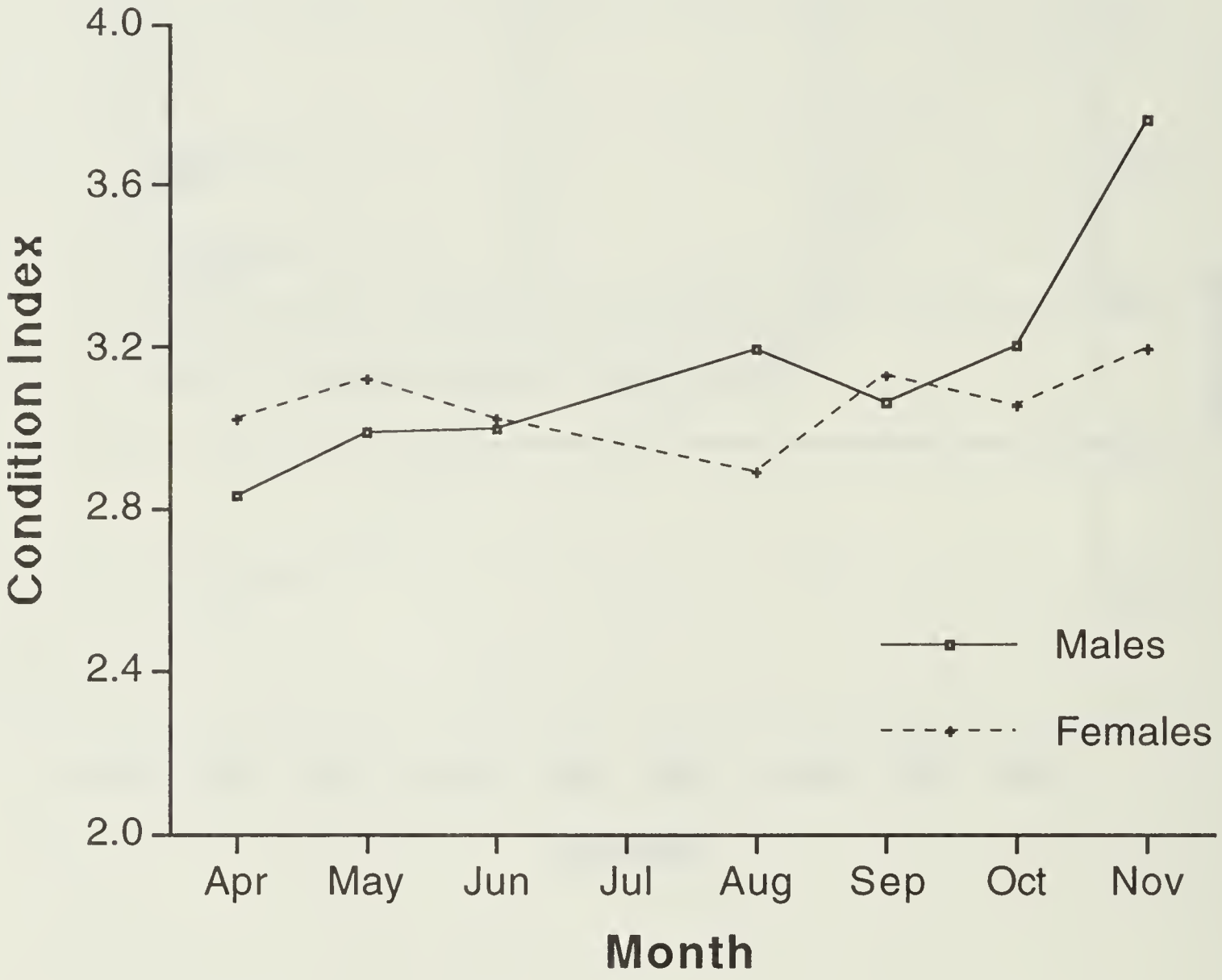


Figure 2. Mean monthly condition indices ((body mass/body length^3) x 100,000) for after-birth-year male (N = 95) and female (N = 69) raccoons in west-central Illinois 1989-93.



Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 257-264

received 12/8/98
accepted 4/25/99

Rana sphenocephala (Southern Leopard Frog) Malformities Found in Illinois with Behavioral Notes

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ABSTRACT

Several malformed southern leopard frogs (*Rana sphenocephala* [*R. utricularia*]) were discovered in a small pond in Southern Illinois. Deformities included missing limbs, split limbs, complete but abnormal limbs, missing eyes, and partial limbs. This study appears to report the first Illinois case of multiple malformities at one site and is apparently the second reported case of malformed southern leopard frogs in the country. The source pond of these frogs needs further study to resolve the many questions about these malformities at this site.

INTRODUCTION

Isolated cases of amphibian malformities have been news since 1920 (Adler, 1958; Anonymous, 1944, 1945. 1954, 1962, 1964; Banta. 1966: Bishop, 1947, 1949: Bishop and Hamilton, 1947; Bjount, 1935; Charles, 1944; Colton, 1922; Cooper, 1958; Cunningham. 1955; DuBois, 1979; Hauver, 1958; Hebard and Brunson, 1963; Hovelacque, 1920; Martinez, et al.,1992; Meyer-Rochow and Koebke, 1986; Mizgireuv, et al., 1984; Reynolds and Stevens, 1984: Rostand, 1958; and Vershinin, 1989). Although reports of malformed Amphibia are not new, the frequency of these reports has increased dramatically in recent years, especially since 1996 (Minnesota Pollution Control Agency [MPCA],1997). Early reports were very rare. By 1995, however, 91 of 95 frogs collected at one site in Meeker Co., Minnesota were abnormal and 54 of Minnesota's 87 counties had reports of deformed frogs (MPCA, 1997).

In Vermont, Ferguson and Levey (In: Allen, 1996) collected more malformed frogs in one day than had been recorded in the state in the past 75 years. Today reports are coming from all around the country as can be seen on the web site of the North American Reporting Center for Amphibian Malformities: http://www.npsc.nbs.gov/narcam/reports/reports.htm. Despite the high levels of industry and agricultural use in the Midwest, few deformities have been reported in this region. Illinois had but one isolated case of amphibian malformities (Assoc. Press, 1996). The present paper describes the anatomy and some related behaviors of a series of malformed southern leopard frogs, *Rana sphenocephala* (*R. utricularia*) discovered in Southern Illinois.

METHODS

On 20 and 25 July 1997 migrant juvenile southern leopard frogs (*R, sphenocephala*) were collected over 2 intensive hand search periods from a small, 1/4 acre, wooded pond on the Southern Illinois University at Edwardsville campus, Edwardsville (Madison County), IL. The 20 July search took place between 1100 and 1200 hours. The 25 July collecting period was performed between 1200 and 1400 hours. The temperature on these days was 35 – 38°C.

RESULTS

All frogs were collected at random from under coarse woody debris on the banks of the pond. Of the 31 *R. sphenocephala* collected on 20 July, one was found on open mud, 25 were found under fallen bark and small (under 5 cm diameter) logs, and four were found under large logs. One normal juvenile bullfrog (*R. catesbeiana*), one normal migrant juvenile gray treefrog (*Hyla versicolor*) identified during spring breeding chorus, and 45 normal migrant juvenile small-mouthed salamanders (*Ambystoma texanum*) were recovered from under bark and logs as well. *Rana sphenocephala* were only found under loose debris. On 25 July, I collected 35 post migrant juvenile *R. sphenocephala*, 32 from under fallen bark and three from under small logs. Thirty-seven post migrant *Ambystoma texanum* were also found. All *A. texanum* and normal *R. sphenocephala* were released.

Upon examination, one *R. sphenocephala* was discovered to possess a split-leg malformity, giving the appearance of five legs. Four other frogs in the sample also showed morphological aberrations of questionable causation. These cases appear to represent the second documented report of malformed frogs in IIIinois (Assoc. Press, 1996), and the first series of such individuals from one location. In addition, there has been only one other report of malformed *R. sphenocephala* in North America (North American Reporting Center for Amphibian Malformations, pers. comm., 1998).

Anatomical Descriptions and Possible Causes

The five-legged frog possessed a "split limb" malformity creating the appearance of a fifth limb (fig. 1). The forelimbs and left, rear limb were normal. The extra limb was representative of a typical left leg, and was complete from the tibiotarsus distally. The extra limb extended cranio-dorsally from the joint of the right tibiotarsus and femur, but the normally-ventral surface faced cranially. The primary right leg was positioned normally, but possessed an incomplete, shortened femoral section shared by both extensions of the split-limb. A swollen area containing the femur appeared on the ventrurn of the pelvic region. This frog died 3 August 1997.

A second frog had a minor, almost unnoticeable malformity in the right rear limb. This leg was not held in the normal sifting posture usually observed in frogs. Typically, the tibiotarsus of the rear limb can be folded flush against the femur portion of the leg in preparation for jumping. Instead, the angle between the femur and tibiotarsus was never held closer than 20 to 30 degrees. Since every other frog in the sample held their rear legs normally, it suggests this was also a developmental abnormality. An alternative explana-

tion is that this frog suffered an injury such as a sprained joint causing it to be unable to fold its leg properly.

The other three frogs could actually represent survivors of predation events, but they are included here because of their association with the split-limbed frog. The third frog was missing its right eye (fig.1). The tibiotarsus of its left leg was visibly shortened, and was missing any remnants of a foot. The right leg was normal through to the distal joint of the tibiotarsus. The right foot was reduced in size and lacking digits. The missing parts of the hind legs may have been caused by crayfish which prey on young froglets as they metamorphose (Tucker, Illinois Natural History Survey, pers. comm., 1997). The fourth frog appeared normal except for the complete absence of a right rear leg.

The fifth frog was missing its front right limb from the elbow distally. The distal end of this limb was swollen and red as if infected or recently amputated. Still, it was similar to pictured malformities of *Ambystoma* induced by Pietsch (1991). This individual was released at the pond.

The cause of these malformities remains unknown, but several alternatives have been suggested at other sites. Harkey and Semlitsch (1988) provided evidence that ornate chorus frog (*Pseudacris ornata*) larvae developing at temperatures between 20°C and 25°C tended to result in relatively fewer malformities than those raised at extremes of 15°C and 30°C. Frogs raised at extreme temperatures often developed partially and totally nonfunctional rear legs. Muto (1969) found that improper temperatures could induce skeletal malformities in unidentified toad larvae (*Bufo*) as well. Air temperature trends during April 1997 were not typical for this region (pers. obs.). Whether acute exposure to freezing temperatures can induce malformities such as those seen at this site is unknown. If *R. sphenocephala* are similarly affected by temperature, the unusually cool temperatures of spring and summer of 1997 may have contributed to malformities at this site.

This pond is located near grass fields that are harvested for hay. Although I have not observed fertilizer or pesticide application on these fields, I have observed personnel of Southern Illinois Unviersity, Edwardsville applying pesticides or herbicides along buildings and lamp posts with "high volume sprayers" with garden hose attachments. This procedure was very sloppy. Chemicals were captured by the wind and the volume of water created runoff. Such spraying could be a partial causal agent of these malformities. Hind limb amphibian malformities have been connected to agricultural use (Bonin. et al., 1997; Hecnar, 1995; Marchal-Segault and Ramade, 1981; Oellet. et al.,1997; Pawar, et al., 1983: Pawar and Katdare,1984; Rzehak, et al., 1977; Schuytema, et al., 1991). If fertilizers or pesticides were applied to these grasslands, this may explain the Edwardsville occurrence.

Methoprene is a commonly applied mosquito control that has been connected to amphibian malformities (Conlon,1996). This compound breaks down into a compound structurally and functionally similar to retinoic acid. Retinoic acid stimulates limb regeneration and has been shown to induce malformities in Amphibia when present at improper levels (Madden, 1993; Pietsch,1991). Mosquitoes are a Public health concern in the St. Louis area due to occurrences of meningitis and encephalitis, consequently, mosquito spraying

is widespread. If Methoprene was applied, it might have mimicked the effects of retinoic acid causing malformities like I have observed.

Cummins (1987) showed that common frog tadpoles (species unknown) developed increased frequencies of deformities when raised at a low pH. This pond received a lot of runoff directly from a neighboring parking lot. Runoff caused the vertical depth of the pond to increase about 5 m above its low point the previous summer. It is possible that products used to melt ice or compounds in the asphalt reduced the pH causing these problems. It is also possible that the asphalt itself is responsible. Furthermore, the fact that this pond is not stream fed, but obtains most of its water supply from the parking lot's runoff, reduces the opportunity for its buffering prior to entering the pond. Such an effect could reduce the pH of the pond significantly. Rain in our area is much more acidic today than in the past. In 1955 it was above 5.6 and by 1984 it was less than 4.5 (Chiras. 1991).

Another possible cause of this problem was suggested for *Hyla regilla* and *Ambystoma macrodactylum* by Sessions and Ruth (1990). They found that a parasitic trematode uses amphibians as intermediate hosts. It buries into the cloacal region of the tadpole and forms a cyst. The presence of this cyst mechanically interferes with limb development resulting in supernumery rear limbs. Since I observed many malformity types other than supernumery hind limbs, this explanation is not adequate.

Whatever the teratogenic factor, the fact that deformed frogs are now documented in Illinois makes further research in this state desirable. This pond is easily accessible for study, and easily enclosed by drift fence materials to monitor migrating juveniles. Such a study would contribute much to our understanding of this problem in Illinois. These specimens were delivered to Dr. Chris Phillips for deposition in the Collection of the Illinois Natural History Survey, Champaign, IL (accession numbers not yet available).

Behavioral Observations

The split-limb impeded the frog's ability to jump. When jumping forward, the extra limb created resistance that prevented much forward movement. Most movements by this frog were restricted to "walking". In addition, the small femur of the 5-legged frog reduced the leverage necessary for saltatory movement. This frog had great difficulty righting itself when turned on its back. The inability to effectively escape predators due to its lowered mobility and dexterity, would make survival of this frog in the wild unlikely.

Its reduced jumping ability also affected the feeding success of the split-limb frog, When a dewinged housefly was dropped on the water surface 1-2 cm from the frog, the frog had not successfully captured it after 6 attempts. The same fly was easily captured by a normal frog in one attempt. It seems that the normal attack behavior of *R. sphenocephala* could not be performed due to the opposing resistance of the extra limb experienced while lunging forward after prey. The only time it could catch prey was when flies were dropped directly on the frog's nose. Consequently, it is unlikely that this frog could survive very long even if it did escape predation.

All the malformed frogs appeared less active than normal individuals. These frogs were held temporarily in a 40 L aquarium. Despite constant movements of the normal frogs, the malformed frogs remained within 5 cm of their original placement in the tank 20 min,

1 hr, and 3 hrs later. This apparently low activity level may be reflective of these frog's malformities and the difficulty with which they moved. It may also represent a selective behavior on the part of these frogs. Frogs with malformities (which reduce their potential for mobilization and consequent escape) are more susceptible to predators. If these frogs continually move about in a habitat filled with snakes, bullfrogs, and other predators; they will quickly be removed from the population by these frog-eaters. Alternatively, if frogs carrying such malformities remain still and resist fleeing; they are less likely to be attacked -especially by movement dependent predators. In such cases these frogs could survive longer, increasing their potential fitness. Reduced activity due to carbaryl has been reported in tadpoles (Bridges, 1997; Semlitsch, et al., 1995).

It would be interesting to raise a number of these frogs to adulthood to determine their survivorship in the absence of predators, the heritability of their malformities, and to investigate some of the behavioral changes necessary for their persistence. It might also be interesting to look at the influence of these deformities on mate choice. Are females able to recognize malformed males visually or by their call alone? Or would these deformities affect the male's reproductive success at all? It would also be interesting to examine the actual economic costs of toxic exposure incurred by amphibians utilizing optimality models.

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Figure 1. Southern leopard frogs, *Rana sphenocephala* (*R. utricularia*) found in Edwardsville, Madison County, Illinois. One frog has its right rear leg malformed as a split limb. It showed reduced activity and had difficulty catching food. The second frog has a missing left eye, reduced and disfigured backbone, and is missing portions of its rear legs. This frog also showed reduced activity levels compared to normal frogs.

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 265-269

received 1/8/99
accepted 4/18/99

Survival of Breeding Age Male White-Tailed Deer in Central and Northern Illinois

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ABSTRACT

Male white-tailed deer (*Odocoileus virginianus*) were captured and marked during 1980-85 in Piatt County (east-central), and during 1990-1992 in Dekalb County (northern) and Brown-Adams Counties (west-central). A total of 117 2-year-old males whose ultimate fate were known were used to examine annual survival of breeding aged males. Annual survival averaged 0.56 ± 0.05 (n = 117) for 2-year-old males, 0.50 ± 0.06 (n = 66) for 3-year-old males, and 0.39 ± 0.09 (n = 33) for 4-year-old males. There were no significant differences in annual survival among study areas or between age classes. Comparison of these data with 1997 computer simulations of the Illinois deer herd suggest that breeding age male survival has not changed appreciably since the early 1980's.

INTRODUCTION

Beginning at age 18 months, male white-tailed deer experience considerably higher mortality than females as the result of breeding-induced behavior of males and hunter selection (Nixon et al. 1991, Roseberry and Woolf 1991). Most hunters and others interested in maintaining high densities of male deer in Illinois frequently argue that males are being exploited at levels that reduce the numbers of older, trophy-sized males. Dominance and breeding success in males are affected by antler size and body weight (Townsend and Bailey 1981, Miller et al. 1987), with the likelihood of successful breeding increasing with male age. Observations of yearling males indicated they are not usually successful breeders in Illinois (Nixon et al. 1994). Two-year -old males are likely the most frequent breeders, based on their greater numbers in the population compared to older males. To date, published data in Illinois have reported survival of yearling males (Nixon et al. 1994), but for adult males have used a composite of all males ≥ 2 years old (Nixon et al. 1991, Nixon et al. 1994, J. Roseberry, Southern Illinois University, computer model for the Illinois deer herd, 1997, unpublished data). If hunter exploitation in

the 1990's is greater than the 1980's in Illinois and is also greater compared to other areas throughout the whitetail range, 2- and 3-year-old males would be expected to experience low survival, leading to a decline in abundance of older males in the population.

METHODS

Males were captured using rocket nets during 1980-85 in Piatt County and 1990-92 in Brown-Adams Counties and Dekalb County (Nixon et al. 1994). Each area contained a mixture of public and private lands and included a wooded public park, which provided deer with abundant diurnal cover throughout the year, protection from severe winter weather, and some protection from firearm hunters. Portions of the public parks in Dekalb and Brown-Adams Counties were open to archery hunting. In addition, about half of the Brown-Adams park was open to firearm hunting beginning in 1992. Most of the adjacent farms on all three study areas were annually open to both archery and firearm hunting. To estimate survival of breeding age males, we used males known to have survived to age 2 after tagging and whose ultimate fate was known. The survival analysis was calculated using the staggered-entry design of the Kaplan-Meier product limit estimator and the log-rank test for homogeneity between groups (Kaplan and Meier 1958, Pollock et al. 1989). Differences in the numbers of males surviving among areas and between age classes were compared using log-likelihood ratios chi-square and for larger samples, Fisher's exact test.

RESULTS

A total of 117 marked males survived to age 2 (Table 1). Survival (mean ± S.E.) of 2-year-old males to age 3 averaged 0.56 ± 0.05 and did not differ among areas ($X^2_{(2)} = 2.9$, $P > 0.23$). Because hunting pressure increased between the 1980's in Piatt County and the 1990's in Dekalb and Brown-Adams Counties (Illinois Dept. Nat. Resources, unpublished data), we tested for a significant difference in the survival rate of 2-year-old males tagged in the combined Dekalb and Brown-Adams Counties and those marked in Piatt County. Annual survival was similar between counties (Fisher's exact test$_{(2)}$, $P > 0.9$).

Survival of 3-year-old males averaged 0.52 ± 0.06 and did not differ among areas ($X^2_{(2)} = 3.38$, $P > 0.18$). Survival of males in Piatt county marked in 1980-85 did not differ significantly from males marked in 1990-92 (Fisher's exact test$_{(2)}$, $P > 0.62$). Survival of 4-year-old males averaged 0.39 ± 0.09 with survival among areas not significantly different ($P > 0.13$). However, sample sizes of marked males were relatively small by age 4 (n = 10, Brown-Adams, n = 7, Dekalb, and n = 16, Piatt) (Table 1). Combining areas, annual survival of 2-, 3-, and 4-year-old males did not differ significantly ($X^2_{(2)} = 3.1$, $P > 0.20$). In central and northern Illinois, < 10 males will survive to their 5th birthday for each 100 2-year-old males (Table 1).

DISCUSSION

Survival of 2-year-old male white-tailed deer varies throughout their range, dependent on hunting pressure. In Illinois, hunting is the ultimate cause, but social status/behavior during the breeding season is the proximate cause of lower survival of males compared to females (Nixon et al. 1991, Roseberry and Woolf 1991). McCullough (1979) found that

2-year-old males were consistently underrepresented in cull removals from the George Reserve enclosure. Older males dominated these 2-year-old males and tended to exclude them from breeding activities, thus reducing their daily movements and vulnerability to harvest. However, Roseberry and Klimstra (1974) reported that yearling and 2-year-old males were overrepresented in the harvest at the Crab Orchard National Wildlife Refuge in southern Illinois. Dasmann and Taber (1956) believed that 2-year-old black-tailed deer males (*Odocoileus hemionus*) were more vulnerable to harvest early in the hunting season because of inexperience with hunters. DeYoung (1989) found lower mortality in 2- and 3-year-old male whitetails compared to older males on 2 private ranches in Texas. However, this may have been the result of more careful selection for larger males by hunters on these ranches.

Our results indicate a gradual decline in annual survival as males grow older in Illinois, with 2-year-old males surviving at higher rates than older males (Table 1). Older males usually grow larger antlers and become even more attractive to hunters, with corresponding increase in harvest mortality. There was no indication that 2-year-old males were dying at very high levels in Illinois. Our marked 2-year-old males survived at higher levels than marked males in Minnesota (0.46, Fuller 1990; 0.47, Nelson and Mech 1986) and Montana (0.40, Dusek et al. 1989) and survival was markedly higher than a radio marked sample in Michigan (0.22, Van Deelen et al. 1997). Males in these more northern states must also survive often harsh winters which kills proportionally more adult males than adult females (Fuller 1990, Nelson and Mech 1986).

Our study areas included some refuge protection from hunting for males and may have improved male survival to some unknown degree. However, refuges from hunting are scattered throughout private lands in central and northern Illinois and may also influence male survival. Radiotagging has shown that breeding-age males wander over large areas during the breeding season (Dusek et al. 1989, Nixon et al. 1994, Sparrowe and Springer 1970). This searching behavior frequently takes these males away from refuge protection onto hunted areas. These movements frequently ocurred on all three of our study areas. Recent (1997) computer modeling of the statewide Illinois deer population indicated that annual survival of adult males ($\geq$ 2 years) averaged about 0.57 (J. Roseberry, Southern Illinois University, personal communication, 1998), which was very close to the annual survival of our marked sample of 2-year-old males. However, the current computer model may be overestimating actual population size by 10-15% (J. Roseberry, personal communication, 1998). If true, the model would underestimate harvest rates and inflate annual survival estimates somewhat above actual numbers. Thus, actual survival of adult males may be slightly below that reported for the tagged males. However, there was no indication that adult males between 2- and 4-years old, the prime breeding age classes in Illinois, were being exploited at excessive levels or that exploitation has changed appreciably since the early 1980's.

ACKNOWLEDGEMENTS

We thank the many landowners that allowed access to their farms and the many volunteers who helped capture deer. This study would not have been possible without the able assistance of L. P. Hansen, P. A. Brewer, J. E. Chelsvig, T. Esker, J. B. Sullivan, R. Koerkenmeier, J. M. Nelson, M. Challon, S. Rueff, and J. Seets. Dr. P. Brown, Illinois

Natural History Survey, reviewed the manuscript. This paper is a contribution (in part) of Federal Aid in Wildlife Restoration, W-87-R, the Illinois Department of Natural Resources, the U.S. Fish and Wildlife Service, and the Illinois Natural History Survey, cooperating.

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Table 1. Number of male white-tailed deer ≥ 2 years old surviving in Brown-Adams Counties (1990-92), Dekalb County (1990-92), and Piatt County (1980-85). Survival values represent the Kaplan-Meier survival functions for the entire cohort (n = 117).

	Number of males alive at age					
County	2	3	4	5	6	7
Brown-Adams	45	22	10	2	0	0
Dekalb	18	9	7	2	0	0
Piatt	54	35	16	9	3	1
Total	117	66	33	13	3	1
Survival		0.56	0.28	0.11	0.03	
(SE)		(0.05)	(0.04)	(0.03)	(0.01)	

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 271-275

received 11/12/98
accepted 3/6/99

Notes on the Diet of Female Bird-Voiced Treefrogs (*Hyla avivoca*) in Southern Illinois

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ABSTRACT

We examined stomach contents of 14 female bird-voiced treefrogs (*Hyla avivoca*) collected in southern Illinois. Adult and larval coleopterans and lepidopterans were the most abundant prey items, whereas hymenopterans (ants), homopterans, and two unidentified insects also were consumed. These data suggest that, like male *H. avivoca*, females of this species forage primarily on arboreal insects.

INTRODUCTION

The bird-voiced treefrog (*Hyla avivoca*) occurs in Austroriparian swamps from South Carolina to Florida, across the Gulf Coast to Louisiana, and north along the Mississippi and Red River Valleys into Oklahoma, Arkansas, Kentucky, Tennessee and extreme southern Illinois (Conant and Collins, 1991; Dundee and Rossman, 1989; Krupa, 1986; Smith, 1961, 1966; Trauth and Robinette, 1990). On 1 January 1999, *H. avivoca* was listed as a state threatened species by the Illinois Endangered Species Protection Board (Redmer and Kruse, 1998; J. Herkert, pers. comm.).

Because *H. avivoca* is secretive and its habitat often is quite inaccessible, little is known about its biology. The non-vocal females rarely are collected (Hellman, 1953), and most natural history information for this species is based on data collected from males (Redmer, 1998). The only previous study of this species' diet was based on the stomach contents of males collected in Arkansas (Jamieson et al., 1993). The objective of this study was to identify food items from a sample of female *H. avivoca* collected in southern Illinois.

MATERIALS AND METHODS

Fourteen adult female *H. avivoca* were collected at seven localities in four southern Illinois counties (Union, Johnson, Pope, Pulaski). Two frogs were collected as they approached males in breeding choruses, 10 were collected when found crossing roads adjacent to breeding choruses, and two were collected on roads in early autumn. All but one was returned to the laboratory, euthanized within 12 hr of capture, fixed in 10% formalin, and preserved in 70% ethanol. One specimen was preserved ca. 48 hr after capture. All specimens were dissected later, the stomachs and intestinal sections (if distended indicating presence of food items) were opened, and food items were removed and stored in individual vials of 70% ethanol. Food items were examined with a dissecting microscope and identified to the lowest possible taxonomic level using keys of Borror et al. (1989).

RESULTS AND DISCUSSION

Food items were found in seven (50%) of the 14 examined specimens. Within this sample, there was an average of 1.75 food items per frog, and 3.5 items for frogs with food items (range=1-5).

Nineteen individual food items (all insects) were recovered (Table 1). Larval and adult coleopterans were the most frequent food items (N=8), comprising 42.1% of the total sample. Identified coleopteran families were Chrysomelidae and Elateridae. Remaining coleopterans were unidentified larvae or adults. Lepidopterans (three unidentified larvae and one adult) were the second most frequently (21.1%) recovered food items. Three (15.8%) hymenopterans, all ants (Formicidae), were found in the stomachs of two frogs. Two (10.5%) homopterans (one cicadellid and one membracid) and remains of two (10.5%) unidentified insects also were recovered.

Several of the insect taxa and life stages (especially adult elaterid and chrysomelid beetles, homopterans, and lepidopteran larvae) we identified usually forage on, or are encountered on above-ground foliage (Milne and Milne, 1996). This indicates that female *H. avivoca* forage while perched in arboreal habitat. Furthermore, the absence of ground-dwelling or grass-dwelling arthropods (e.g., Isopoda; Orthoptera: Acrididae, Gryllidae) also indicates that these treefrogs forage above ground. Male *H. avivoca* collected in Arkansas specialized on arboreal ants (*Cremastogaster* sp.), which comprised 72% of their diet (Jamieson et al., 1993). The ants in our sample could not be identified to genus. Although it is possible that these ants also were arboreal species, they could have been terrestrial species ingested while these frogs moved over land toward breeding areas. The closely related gray treefrogs (*H. chrysoscelis*, *H. versicolor*) reportedly feed

extensively on arboreal elaterids as well as terrestrial harvester ants (*Pogonomyrmex)*, indicating that they forage on ground as well as in elevated habitats (Ralin, 1968). The diet of the green treefrog (*H. cinerea*) consists primarily of arboreal insects as well as terrestrial ones (Brown, 1974; Freed, 1982). *Hyla cinerea* also is an Austroriparian species that reaches its northern range limit in southern Illinois (Smith, 1961). However, unlike *H. avivoca*, the former species is more of a habitat generalist and it is expanding its range in the state (Redmer, et al., in press).

Although our sample size was moderately small (N=14 frogs, seven with stomach contents), this study indicated that female *H. avivoca* forage primarily above ground, and that this species is much more habitat-specific than are closely related or syntopic congeneric treefrogs. Recent studies of this species in Illinois also indicate that it is highly specialized (Redmer, et al., in press). Large choruses occur primarily in remnant Austroriparian swamps with stands of mature baldcypress (*Taxodium disticum*) and/or tupelo (*Nyssa aquatica*) trees and a dense canopy (Redmer, et al., in press). Because *H. avivoca* now is listed as a state threatened species in Illinois, further quantified studies of its habitat are desirable.

ACKNOWLEDGMENTS

We thank R.A. Brandon (Southern Illinois University at Carbondale) and three anonymous reviewers for commenting on the manuscript. M. Blanford (Timberline Fisheries, Marion, Illinois), B. Burke, M. DeJesus, and A. Wilson (Southern Illinois University at Carbondale) assisted with the field work, portions of which were supported by a Nature Conservancy contract with Southern Illinois University at Carbondale.

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Table 1. Frequency of food items (N=19) found in the digestive tracts of seven female *Hyla avivoca* collected in southern Illinois.

Food	Taxa	Percent of Sample	Number of Items
Insecta			
	Coleoptera	42.1	8
	Chrysomelidae	(5.3)	1
	Elateridae	(15.8)	3
	Unidentifiable larva	(5.3)	1
	Unidentifiable adults	(15.8)	3
	Hymenoptera	15.8	3
	Formicidae	(15.8)	3
	Lepidoptera	21.1	4
	Unidentifiable larvae	(15.8)	3
	Unidentifiable adults	(5.3)	1
	Homoptera	10.5	2
	Cicadellidae	(5.3)	1
	Membracidae	(5.3)	1
	Unidentifiable	10.5	2

Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 277-283

received 1/8/99
accepted 6/2/99

Translocations of Amphibian Species Outside Their Native Range: A Comment on Thurow (1994, 1997)

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ABSTRACT

We question the rationale and methodology behind two recent amphibian translocations into west-central Illinois. In both cases, species were translocated outside their native ranges and no rigorous criteria for gauging success were utilized. We are concerned that translocations such as these will give the mistaken impression that new populations of amphibians can be easily established, even in marginal habitats, and that any translocation effort will result in successful amphibian conservation.

INTRODUCTION

The current status of amphibian distribution and abundance is generating much concern among herpetologists, conservation biologists, natural resource managers, and the general public (Wyman, 1990; Blaustein et al., 1994). Dramatic declines in local populations, malformations, and extirpations have been reported while impacts of acid rain, ultraviolet radiation, pollution, pesticide use, and habitat loss are the focus of much research. While no one factor has been established as the major cause underlying these declines, interest in identifying and ameliorating these factors and their negative effects on amphibian populations is high.

Concerns over declining amphibian populations are compounded by the fact that most amphibians are poor colonizers of unoccupied habitats (Petranka, et al., 1993), especially where habitat is fragmented by development or agriculture and dispersal corridors are limited or absent. The combination of low vagility and population declines has resulted in renewed interest in translocations of amphibians to suitable habitats. The ability to collect many individuals from a few areas or move egg masses from known breeding sites has contributed to the increase in the popularity of amphibians as translocation subjects. As pointed out by Dodd and Siegel (1991), however, caution should be exercised when considering translocation as a potential conservation measure, especially for endangered or threatened species.

Thurow (1994,1997) described efforts to translocate two species of amphibians into west-central Illinois. While these studies contribute some basic biological information for the species involved (the wood frog, *Rana sylvatica* and the two-lined salamander, *Eurycea cirrigera*), we question several aspects of the rationale for these translocations, the interpretation of data, and especially the implications for amphibian conservation.

TRANSLOCATION RATIONALE

Thurow (1994, 1997) suggests that *E. cirrigera* and *R. sylvatica* formerly occurred in west-central Illinois and that anthropogenic causes or recent climate change have caused range contractions. For *E. cirrigera*, the species' current U.S. range is described as "N, S, E, and even W (in Mississippi and Louisiana)" of west-central Illinois as evidence of past existence in this part of the state. However, the current distribution of *E. cirrigera* (Fig. 1a) actually argues against its existence in west-central Illinois. There are no records for northern Illinois or the states of Wisconsin or Michigan. With the exception of the Kankakee and Will county populations, there are no known records of *E. cirrigera* in Illinois outside the Wabash-Ohio river drainage (Smith, 1961; Mierzwa, 1989). A more plausible scenario, suggested by Smith and Minton (1957), is that the range of *E. cirrigera* has been determined by the distribution of the eastern deciduous forest, which has been fairly stable in Illinois since the end of the Hypsithermal Interval, 6,000 years before present (YBP) (Webb and Bryson, 1972).

Thurow (1994) cites *R. sylvatica* records from Peoria and Rock Island counties as evidence that this species historically occurred in west-central Illinois. The Peoria County record, although accepted by Smith (1961), is unverified and both records are subject to question (Redmer, 1998). We believe the current distribution of *Rana sylvatica* was restricted by the development of the Prairie Peninsula (sensu Transeau, 1935) during the Hypsithermal Interval 8,000 - 6,000 YBP (Smith 1957). The historic and, in some cases, current distributions of many species of plants and animals are restricted to or by the Prairie Peninsula. Such distributions can be observed in Illinois plants (Mohlenbrock and Ladd, 1978), amphibian and reptiles (Smith and Minton, 1957; Bock, et al., 1981) and mammals (Hoffmeister, 1989). In particular, this is likely true for species of low vagility or colonizing potential that depend on moist, closed forest communities for their survival such as forest amphibians. The Illinois range map for *R. sylvatica* (Fig. 1b) exemplifies this biogeographic effect. The historic range of *R. sylvatica* almost certainly did not include large portions of the Prairie Peninsula.

While it is possible that *E. cirrigera* and *R. sylvatica* may have occurred in west-central Illinois over geologic time, as did black spruce, red pine, and hemlock (King, 1981), there is no evidence that either species existed in west-central Illinois.

DATA INTERPRETATION

Thurow (1994,1997) suggests more can be learned about habitat restrictions and possible conservation measures from these translocations. However, we see no evidence of any control populations being monitored in existing or, more appropriately, donor habitats. Without past or concurrent information on breeding success within known ranges, the significance of the data and interpretations is weakened.

We also raise questions regarding some of the ". . . useful information (that) has been generated" (Thurow, 1997; 85-86). Specifically:

"(1) Translocations of about 200 individuals appears sufficient to establish a colony in good habitat. The number could be smaller."

We do not believe that Thurow (1997) provides adequate data to demonstrate minimum numbers of translocated individuals to establish viable populations. It appears from the methods that animals were continually released over several years at Thurow's sites as collections at the donor sites permitted. In the 4 sites deemed successful (1,2,4, and 6), 504, 304, 496, and 223 animals were released (mean = 382). Further, because introductions continued to take place after the first sign of reproduction, it is not known whether subsequent reproduction can be attributed to an "established" population or the release of additional individuals. Finally, the minimum number of individuals required to achieve any sign of reproduction cannot be considered to be the minimum founder population size until further and continued reproduction, without additional releases, is documented.

"(2) Under special circumstances, the wet area occupied by a colony can be less than $200m^2$, or even $26m^2$ of stream bottom."

Over the short term, this appears to be true. However, the long term persistence of populations in such small and isolated habitats is questionable at best. Indeed, if *E. cirrigera* may have occurred in west-central Illinois, the small and widely scattered distribution of suitable microhabitats and their distance from the main species range in the eastern United States could explain its extirpation from the area over geologic time. Small, isolated populations are far more prone to extinction than larger populations or those closer to the main range (Noss and Cooperrider, 1994 and references therein).

"(3) Two-lined salamanders can survive in drier west-central Illinois, when more suitable habitat is found or created".

Data from sites 1 and 2, at least, strongly suggest that *E. cirrigera* can persist for some time when placed in a suitable microhabitat. As a region, however, west-central Illinois receives approximately 2.5cm less precipitation than eastern Illinois, where *E. cirrigera* occurs naturally (Fentem, 1996; Neely & Heister, 1987) Thurow's data do suggest that when drought causes seeps and springs to cease flowing, (sites 3& 4), reproduction and/or survival may be severely reduced. Droughts and drought severity appear to be as common in eastern Illinois and west-central Illinois (Neely & Heister, 1987).

"(4) Although the preferred habitat is clear rock-bottomed streams in forested areas, seepage slope films can also be used, particularly if there are seepage pools downstream."

Many plants and animals may persist and reproduce in marginal habitats but the long term viability of such populations is extremely tenuous (Maurer, 1986). In the case of forest-interior birds in small woodlots, populations are almost exclusively maintained by immigration of individuals born elsewhere (Robinson, et al., 1995). No data are presented that compare salamander population ecology in these seepages and springs with that in its preferred native habitat.

"(5) Pristine sites are not necessary and survival can occur in selectively lumbered redeveloping oak-hickory forest."

If *E. cirrigera* was limited to pristine forest, it would be a rare animal indeed. Within its native Illinois range, only 1552 acres of high quality mesic forest remain (White, 1978) yet *E. cirrigera* is not a rare animal in this area (Smith, 1961; Mierzwa, 1989).

"(6) Devegetation of drainage basins tend to cause xerification and loss and deterioration of surface waters and stream flow regimes, and should be avoided in and around nature preserves for semiaquatic animals like the two-lined salamander."

We do not argue the potential truth of this statement. However, we can find no data in Thurow (1997) that tests or supports this assertion. Further, references used to support this statement (e.g. Bowman, 1991; Sheperd, 1975; Visocky, 1993) do not relate these impacts to amphibians but rather acknowledge that, in general, droughts occur and can lower water tables, deforestation can lead to drier ground conditions and higher water temperatures, and deteriorating water quality can impact stream biota. Studies that have investigated these effects specifically on herps would have been far more appropriate.

IMPLICATIONS FOR AMPHIBIAN CONSERVATION

A common goal of conservation is to protect, maintain, and enhance viable populations over the long-term. Most, if not all, conservation biology literature suggests that this is best done by protecting core populations and landscapes and by protecting or providing biological linkages of value to the populations of concern (e.g. Noss & Cooperrider, 1994 and references therein). The introduction of species well outside their historic ranges creates isolated populations that will likely not contribute to the long-term persistence of the species. Such efforts would seem to be more closely associated with captive breeding programs of arboreta, aquaria, and zoos than the stewardship of biological systems in the field.

Of concern to us is the implication from Thurow (1997) that mitigating damage to natural populations can be easily achieved by creating new populations almost anywhere. We are especially concerned about the "attractiveness" of such conservation measures for species in which a large numbers of individuals or their propagules can be easily collected (e.g. some plants, and many amphibians).

Translocation and reintroduction are arguably the most visible and publicly interesting methods of species protection, much more so than habitat protection or management, and

frequently proceed with less political controversy. Indeed, one of the first questions asked of one of us (RES) when rare species are put at risk by a particular action is "Can't you move them somewhere else?". Reviews of translocation efforts have suggested that success is low (Dodd & Seigel, 1991) and even those numbers may be inflated by the lack of reporting all failed attempts. In our opinion, translocation should be the method of last resort, yet the notion of "moving them" is widely held by the general public.

We do not suggest that Thurow (1997) advocates widespread releases of amphibians. Indeed, Thurow (1994) provides some guidelines for conducting species releases, including that they should not: 1) be done for no reason, 2) over-collect donor populations, 3) place released animals far outside of the region or biome they came from, nor 4) greatly alter any patterns of genetic polymorphisms that may exist. To this we would most strongly add that if releases are biologically justified, they should be done within the known recent or current range of the species and as close to core populations as feasible. The implication that amphibian conservation can be achieved by creating small, isolated population outside the species known range does a disservice to efforts to promote the stewardship of Illinois' natural heritage and the concept of ecosystem management.

ACKNOWLEDGMENTS

The authors thank Christopher A. Taylor, Kevin S. Cummings, and 3 anonymous reviewers for helpful comments on an earlier draft of the manuscript.

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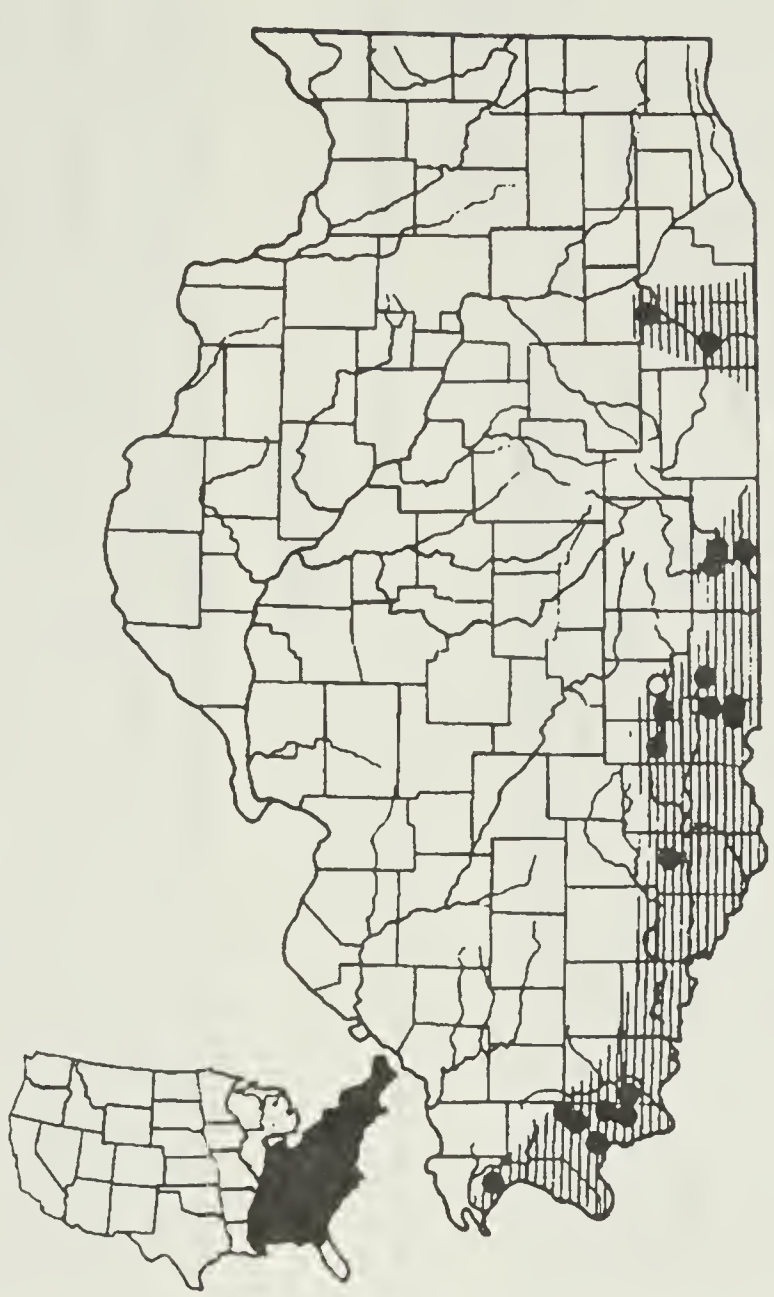
Figure 1. a) Illinois and United States distribution of the two-lined salamander, *Eurycea cirrigera* (formerly *E. bislineata*) and b) the wood frog, *Rana sylvatica* from Smith (1961).



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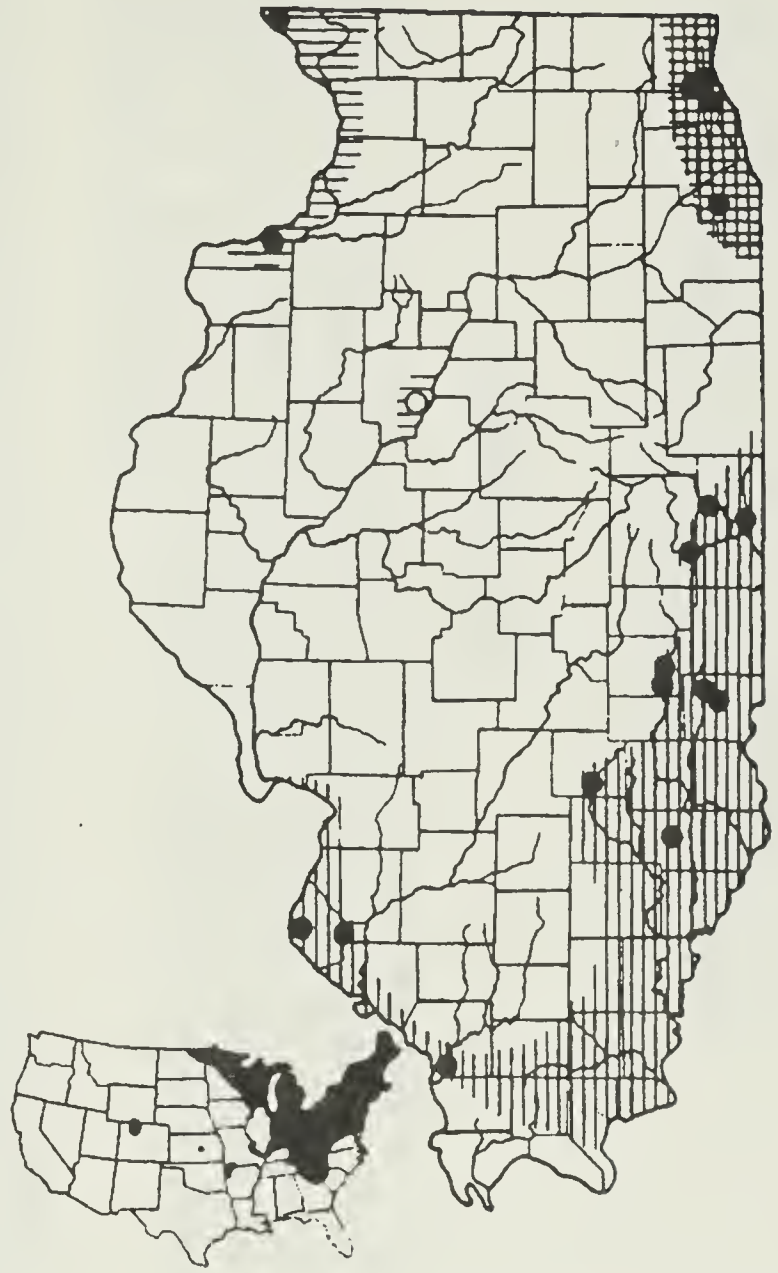

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Transactions of the Illinois State Academy of Science
(1999), Volume 92, 3 and 4, pp. 285-288

received 10/15/98
accepted 1/23/99

Oological Notes from Jasper County, Illinois

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INTRODUCTION

With the passage of the Migratory Bird Treaty Act (1918), the common practice of collecting eggs and nests was outlawed and scientific collecting closely regulated. The formal study of eggs and nests, oology, declined significantly thereafter. However, collecting during the nineteenth century had established large collections in the United States. A survey by Banks et al. (1973) found 638,840 nests or eggs and 4.2 million skins in collections in the United States and Canada.

Clutch sizes are frequently reported in studies of individual species, and parasitism by Brown-headed Cowbirds (*Molothrus ater*) has been an active field of investigation recently (e.g., Robinson 1992, Robinson et al. 1995). In recent decades, notes on egg dates have been made largely from incidental locations and compiled within local or regional treatments (e.g., Bohlen 1989). Egg dates are not often reported when a large sample of nests of many species are available from one location.

Knowledge of local nesting dates allows managers to minimize disturbance and destruction of breeding birds through restricting access and timing management practices such as cutting/haying, cultivation and prescribed burning. Likewise, investigators can appropriately time nest searching effort, both for efficiency and to avoid seasonality biases. Given the paucity of such natural history records from southeastern Illinois, we report on clutch sizes, egg dates and parasitism rates derived from 1,386 nests of 28 bird species from Jasper County, Illinois.

METHODS

We conducted nest searches of Prairie Ridge State Natural Area, Jasper County, Illinois, from May to mid-August 1996 and early-April to mid-August 1997 and 1998. Crews of three to eight people searched the grasslands primarily for the nests of Dickcissels (*Spiza americana*), Eastern Meadowlarks (*Sturnella magna*), Grasshopper Sparrows (*Ammodramus savannarum*) and Field Sparrows (*Spizella pusilla*). In addition, nests of Northern Harriers (*Circus cyaneus*) were monitored from 1994-1998. During 1997 and 1998, the searches included shrub-nesting species, both within Prairie Ridge State Natural Area and on adjacent private lands.

Nests were marked with flagging tape 10 to 25 m from the nest site. Nests of passerines were checked twice per week until fate was determined. Nests of nonpasserines were checked infrequently (less than one check per two weeks) or left undisturbed until after we believed hatching had occurred.

For each species, the mean and observed range in clutch sizes are presented (Table 1). Nests depredated during the laying stages are excluded from these calculations. Egg dates extend from the first egg laid in a nest until hatching. For nests found during incubation, we assumed the first egg day to be clutch size-1 day(s) before location (based on one egg laid per day, with the final egg being laid the same day as nest discovery). This approach is conservative, since nests could be well-advanced in incubation when located. For nests found in the nestling stage, we back-calculated egg dates from nestling age (date of hatch), through incubation time (Ehrlich et al. 1987, E. Kershner and J. Walk pers. obs.), and the number of days equal to only one-half clutch size (to err on the side of conservatism). These dates are compared to Illinois egg dates published in Bohlen 1989 or noted by V. Kleen in The Meadowlark volumes 1-7 (Table 1). If observed, the rate of nest parasitism is noted by species (Table 1).

RESULTS

Oologic notes from 1,386 nests of 28 species are listed in Table 1. Clutch sizes and egg dates observed in this study conform to other published records, although our egg dates for many species are up to ten days earlier or later than those reported. For a few species, egg dates are extended by several weeks. We recorded Mallards (*Anas platyrhynchos*), Northern Harriers, Greater Prairie-Chickens (*Tympanuchus cupido*), Short-eared Owls (*Asio flammeus*), Brown Thrashers (*Toxostoma rufum*), Eastern Towhees (*Pipilo erythrophthalmus*) and Red-winged Blackbirds nesting two weeks or more earlier than previously reported. American Bittern (*Botarus lentiginosus*), Greater Prairie-Chicken, Northern Mockingbird (*Mimus polyglottos*) and Grasshopper Sparrow eggs were found more than two weeks after other Illinois egg dates.

Nest parasitism by Brown-headed Cowbirds ranged from 0% to 19% among passerines with samples greater than 30 nests. One Greater Prairie-Chicken nest was found "parasitized" with two Ring-necked Pheasant (*Phasianus colchicus*) eggs. A single Mourning Dove (*Zenaida macroura*) nest contained four eggs, with intraspecific parasitism being a likely explanation for this abnormal clutch size. One Eastern Meadowlark nest contained two Northern Bobwhite (*Colinus virginianus*) eggs.

DISCUSSION

Nests initiated before late-March and after early-August were likely under-represented or absent from our sample of nests due to our April-to-August field seasons. Egg dates for early nesting species (e.g., Mallards) may be earlier than we report. Likewise, species nesting later in the summer (e.g., American Goldfinches, *Carduelis tristis*), likely have egg dates considerably later than we report.

The parasitism of prairie-chickens by pheasants and of meadowlarks by bobwhites has been previously documented. In the recent past, pheasant parasitism has been a serious

impairment to prairie-chicken recruitment on the area, with rates as high as 43% recorded in the mid-1980s (Westemeier et al. 1998). Control programs have been effective in reducing the pheasant population at this site; only one prairie-chicken nest found since 1988 has contained pheasant eggs (Westemeier et al. 1998, E. Kershner and J. Walk, unpubl. data, S. Simpson, T. Esker, R. Westemeier, pers. comm.). The pheasant eggs were removed by Illinois Department of Natural Resources biologists, and 15 prairie-chicken eggs eventually hatched from this nest. In the meadowlark nest, the female incubated the clutch and fledged five meadowlarks. The bobwhite eggs did not hatch. Northern Bobwhite are known to lay eggs in other bobwhite nests, meadowlark nests, and even within the nests of domestic bantam chickens (Roseberry and Klimstra 1970, Bent 1958, Stoddard 1931).

ACKNOWLEDGMENTS

We would like to thank the Illinois Department of Natural Resources, Illinois Nature Preserves Commission, The Nature Conservancy, AmerenCIPS and several private landowners for access to properties. Funding for our research was provided by the University of Illinois, the Illinois Council on Food and Agricultural Research (C-FAR), and the Illinois Wildlife Preservation Fund.

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Table 1. Mean and range in clutch sizes, early and late egg dates, and parasitism rates of bird nests from Jasper County, Illinois.

YEARS	SPECIES	N	CLUTCH SIZE Mean	Range	EGG DATES Early	Late	Previously Reported	PARASITISM**
1997-98	Mallard, *Anas platyrhynchos*	40	9.40	6 - 13	3/20	7/2	early April - 7/8	
1996,98	American Bittern, *Botarus lentiginosus*	2	4.50	4 - 5	5/20	7/1	5/18 - 6/16	
1994-98	Northern Harrier, *Circus cyaneus*	27	4.37	2 - 7	4/12	7/1	late April - 7/3	
1997-98	Greater Prairie-Chicken, *Tympanuchus cupido*	19	12.8	9 - 17	4/6	7/5	4/20 - 6/6	5% - Ring-necked Pheasant
1997-98	Northern Bobwhite, *Colinus virginianus*	5	17.0	14 - 20	4/15	6/20	May - June	
1997-98	Killdeer, *Charadrius vocifera*	3	3.33	3 - 4	3/27	4/27	3/31 - 8/5	
1997-98	Upland Sandpiper, *Bartramia longicauda*	5	4.00	4	5/16	6/17	mid-May - mid-June	
1997-98	American Woodcock, *Scolopax minor*	4	3.50	3 - 4	<3/20	6/13	3/30 - 6/12	
1997-98	Mourning Dove, *Zenaida macroura*	61	2.00	1 - 4	3/29	8/17	2/4 - early November	2% - Mourning Dove
1998	Short-eared Owl, *Asio flammeus*	3	4.00	3 - 5	3/15	4/22	4/1 - 5/10	
1997-98	Eastern Kingbird, *Tyrannus tyrannus*	4	3.25	3 - 4	6/10	7/9	5/2 - 7/27	
1997-98	Blue Jay, *Cyanocitta cristata*	6	4.73	4 - 5	4/19	5/20	4/12 - 7/12	
1997-98	American Robin, *Turdus migratorius*	55	3.76	2 - 5	4/5	7/31	4/18 - 7/20	
1997-98	Northern Mockingbird, *Mimus polyglottos*	24	3.68	3 - 6	4/7	7/30	4/8 - 7/4	
1997-98	Brown Thrasher, *Toxostoma rufum*	90	3.80	2 - 5	4/9	7/12	4/29 - 7/11	1% - Brown-headed Cowbird
1997-98	Loggerhead Shrike, *Lanius ludovicianus*	17	5.72	4 - 7	4/4	5/26	3/24 - 5/29	
1997	Bell's Vireo, *Vireo belli*	4	4.00	4	6/5	6/30	5/25 - 7/6	50% - Brown-headed Cowbird
1997-98	Common Yellowthroat, *Goethlypis trichas*	9	3.88	3 - 4	5/16	7/7	5/7 - 7/9	11% - Brown-headed Cowbird
1997-98	Northern Cardinal, *Cardinalis cardinalis*	17	2.72	2 - 4	4/12	7/7	4/15 - 8/12	27% - Brown-headed Cowbird
1996-98	Dickcissel, *Spiza americana*	431	3.76	2 - 5	5/14	8/16	5/17 - 8/5	<1% - Brown-headed Cowbird
1998	Eastern Towhee, *Pipilo erythrophthalmus*	2	2.00	2	4/22	6/25	5/11 - 8/1	50% - Brown-headed Cowbird
1996-98	Field Sparrow, *Spizella pusilla*	109	3.61	2 - 5	4/27	7/29	4/20 - 8/20	10% - Brown-headed Cowbird
1997-98	Vesper Sparrow, *Pooectes grammineus*	4	3.50	3 - 4	5/1	8/1	5/9 - 8/4	25% - Brown-headed Cowbird
1996-98	Grasshopper Sparrow, *Ammodramus savannarum*	49	3.87	2 - 6	5/15	7/26	5/18 - 7/10	2% - Brown-headed Cowbird
1997-98	Song Sparrow, *Melospiza melodia*	36	4.20	3 - 6	4/10	7/31	4/22 - 8/7	19% - Brown-headed Cowbird
1997-98	Red-winged Blackbird, *Agelaius phoeniceus*	121	3.35	1 - 5	4/27	7/20	5/12 - 7/23	<1% - Brown-headed Cowbird
1996-98	Eastern Meadowlark, *Sturnella magna*	231	4.34	2 - 6	4/8	7/19	4/6 - 7/23	<1% - Northern Bobwhite
1997-98	American Goldfinch, *Carduelis tristis*	8	5.18	4 - 6	7/27	8/17	6/4 - 8/27	

** No parasitism was observed unless otherwise noted.

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Theodore R. Chauvin
Northern Illinois University
Alteration of UVC-Induced HIV-1 LTR CAT Activity by Vitamin E

Kelly Davidson
Southern Illinois University - Carbondale
Characterization of the Mutant Sperm Cells of the Fern *Ceratopteris richardii*

Thomas O'Grady Johnson
Southern Illinois University - Carbondale
The Occurrence and Role of Actin in the Anterior Ridge of the Sperm Cell of a Fern

Brandy L. Little
Southern Illinois University - Carbondale
Testing Models of Fault-Related Folding, Northern Channel Islands, California

Stephanie A. Stewart
Eastern Illinois University
The Effect of Forest Fragmentation on Genetic Variation and Dispersal of the Flying Squirrel in Illinois

For information on Research Grant Applications (due in April and October) contact:
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Paul Krasucki
Southern Illinois University - Edwardsville
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Transactions of the Illinois State Academy of Science
Volume 92 (1999)

CONTENTS

Academy of Science Editorial Information..... inside front cover

Agriculture Papers

Khanna, Anupama Q., Victoria A. Borowicz, and Marjorie A. Jones
Effects of Nitrogen Fertilizer and Defoliation on Growth, Foliar Nitrogen, and Foliar Coumestrol Concentrations of Soybean 167

Botany Papers

Kovacs, R. L. and W. J. Sundberg
Syzygites megalocarpus (Mucorales, Zygomycetes) in Illinois 181

Environmental Science Papers

Houpis, James L.J., Hugo H. Rogers, John A. Helms, and Mark P. Costella
Translocation of Carbon-14 in *Pinus Ponderosa* Seedlings Subjected to Long-term Sulfur Dioxide and Water Stress 191

Health Sciences Papers

Christopherson, Jeff, Volkan Sumer, Don Kirkendall, and Marjorie A. Jones
Effects of Exercise Detraining on Lipid Storage in Rats 203

Zoology Papers

Anton, Thomas G.
Current Distribution and Status of Amphibians and Reptiles in Cook County, Illinois 211

Dreslik, Michael J.
Dietary Notes on the Red-eared Slider (*Trachemys scripta*) and River Cooter (*Pseudemys concinna*) from Southern Illinois 233

Dyer, William G.
Newly Reported Snake Hosts for Two Ochetosomatid Digeneans in Illinois 243

Mankin, Philip C., Charles M. Nixon, Joseph B. Sullivan, Terry L. Esker, Robert G. Koerkenmeier, and Laura L. Hungerford
Raccoon (*Procyon lotor*) Survival in West-Central Illinois..... 247

McCallum, Malcolm L.
Rana sphenocephala (Southern Leopard Frog) Malformities Found in Illinois with Behavioral Notes 257

Nixon, Charles M. and Philip C. Mankin
Survival of Breeding Age Male White-Tailed Deer in Central and Northern Illinois 265

Redmer, Michael, David H. Jamieson, and Stanley E. Trauth
Notes on the Diet of Female Bird-Voiced Treefrogs (*Hyla avivoca*) in Southern Illinois 271

Szafoni, Robert E., Christopher A. Phillips, and Michael Redmer
Translocations of Amphibian Species Outside Their Native Range: A Comment on Thurow (1994, 1997) 277

Walk, Jeffery W., Eric L. Kershner, and Richard E. Warner
Oological Notes from Jasper County, Illinois 285

Awards and Announcements..... 289

Contributor Information ..... inside back cover